Seven Sisters Waterfall, in Geiranger fjord in Norway. 410 metres high waterfall

Αρ. 154 – ΣΕΠΤΕΜΒΡΙΟΣ 2021

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ΕΛΛΗΝΙΚΗ ΕΠΙΣΤΗΜΟΝΙΚΗ ΕΤΑΙΡΕΙΑ ΕΔΑΦΟΜΗΧΑΝΙΚΗΣ & ΓΕΩΤΕΧΝΙΚΗΣ ΜΗΧΑΝΙΚΗΣ

Τα Νέα της Ε Ε Ε Ε Γ Μ

154

Θεοδόσης Π. Τάσιος «Κραυγαλέως παράλογο το αίτημα κομματικής πολιτικής στην Παιδεία»

«Το αποτέλεσμα οποιασδήποτε νομοθεσίας Παιδείας θα κριθεί στην πράξη μετά από 15 χρόνια – ενώ μια κυβέρνηση διαρκεί 4 χρόνια, ο δε υπουργός 2 χρόνια συνήθως» επισημαίνει ο Θεοδόσης Τάσιος

«Ξέρετε κανένα ελληνικό κόμμα που να έχει δημοσιεύσει την εθνικώς αναγκαία 500σέλιδη Λευκή Βίβλο της Παιδείας με τις αιτιολογημένες προτάσεις του κόμματός του;» αναρωτιέται μιλώντας στο «Βήμα» ένας σοφός της Παιδείας μας: Ο κ. **Θεοδόσης Τάσιος**, ακαδημαϊκός, πολιτικός μηχανικός, αρθρογράφος και συγγραφέας ήταν εκεί όταν εξελίσσονταν επί δεκαετίες οι συζητήσεις για αναμόρφωση της επαγγελματικής εκπαίδευσης της χώρας. Ήταν εκεί όταν ξεκινούσαν εκπαιδευτικές μεταρρυθμίσεις (η μία μετά την άλλη), κάποιες με όραμα, αλλά ποια με προοπτική; Όταν οι κυβερνήσεις έχουν όριο ζωής τεσσάρων ετών και οι υπουργοί μετά βίας δύο έτη και όταν η έλλειψη πολιτικής συναίνεσης οδηγούσε πάντα το ένα πολιτικό κόμμα να ανατρέπει πλήρως τη φιλοσοφία του προηγούμενου πώς να έχουμε ορατά αποτελέσματα, λέει ο ίδιος στη συνέχεια μιας συζήτησης αφιερωμένης στην Παιδεία.

«Η θεμελιώδης λύση θα ήταν να αλλάξουμε το ήθος μας» δηλώνει ο κ. Τάσιος, θυμίζοντας τη σχέση της πολιτικής με την ηθική. Αλλά πάλι και αυτό πρόβλημα Παιδείας δεν είναι; Η συζήτησή μας καταλήγει στις παρακάτω σκέψεις:

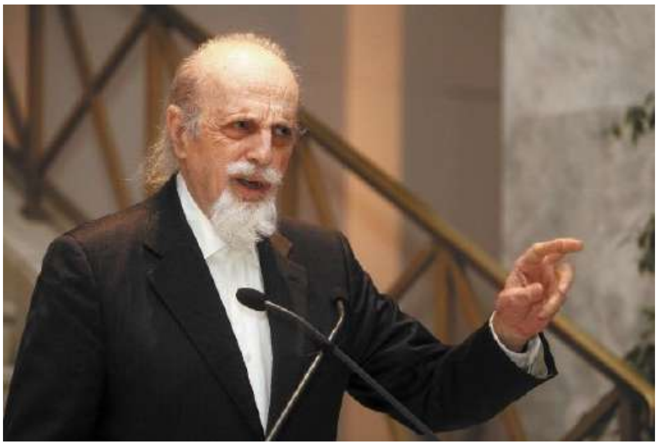
(συνέχεια στην σελίδα 3)

Π Ε Ρ Ι Ε Χ Ο Μ Ε Ν Α

(συνέχεια από την 1η σελίδα)

Τι λέτε λοιπόν σήμερα για την Παιδεία μας; Περνούν οι δεκαετίες, περνούν οι κυβερνήσεις, τρέχουν οι μεταρρυθμίσεις της Παιδείας και μάλλον έχουμε την εντύπωση ότι δεν προχωράμε ουσιαστικά. Πού νομίζετε ότι οφείλεται το φαινόμενο;

«Εκ πρώτης όψεως, μπορεί κανείς πράγματι να σχηματίσει μια τέτοιαν εντύπωση. Ωστόσο, δεν θα τη συνυπογράψω συνολικώς. Θα μπορούσαμε να αναφέρουμε κάμποσα θέματα στα οποία έχει όντως επιτευχθεί πρόοδος. Παρά ταύτα, το θέμα «Παιδεία» είναι τόσο οξύ και τόσο θεμελιακό για τον λαό μας, ώστε αυτά που έχουν επιτευχθεί να είναι εμφανώς ανεπαρκέστατα. Το χειρότερο μάλιστα είναι ότι δεν φαίνεται να έχομε συναίσθηση της πρωταρχικής σημασίας του ζητήματος Παιδεία. Επιτρέψτε μου λοιπόν να αναφερθώ κάπως λεπτομερέστερα σ' αυτό το θέμα. Εάν οι αναγνώστες σας πλήξουν για λίγο, τότε αφενός μεν μπορεί να είναι δείγμα της ανικανότητάς μου, δεν αποκλείεται όμως αυτή η πλήξη να συνιστά και μιαν ίσως ένδειξη ορθότητας της υποψίας μου ότι η πλειονότητα των συμπολιτών μας θεωρούν την Παιδεία ως μιαν απαραίτητη μεν, αλλ' εργαλειακή λειτουργία.



«Το αποτέλεσμα οποιασδήποτε νομοθεσίας Παιδείας θα κριθεί στην πράξη μετά από 15 χρόνια – ενώ μια κυβέρνηση διαρκεί 4 χρόνια, ο δε υπουργός 2 χρόνια συνήθως» επισημαίνει ο Θεοδόσης Τάσιος.

Έχω διατυπώσει τον ευμνημόνευτον κανόνα «Παιδεία είναι εισπνοή παρελθόντος και εμ-πνοή μέλλοντος». Θέλουμε να δώσουμε στην επόμενη γενιά ό,τι έχει κατορθώσει η ανθρωπότητα, αλλά θέλουμε και μια γενιά ευτυχισμένη και δημιουργική για το μέλλον. Ετούτα τα τελευταία βέβαια δεν επιτυγχάνονται μόνον με απλή «μετακένωση γνώσεων και δεξιοτήτων»: κάτι τέτοιο θα οδηγούσε γρήγορα σε αποτελμάτωση, χωρίς την κριτική και τη δημιουργική ικανότητα του παιδιού (θυμηθείτε να του τις αναπτύξετε) και χωρίς την ευδαιμονία που χαρίζει η Τέχνη και το υπαρξιακό βάθος που αποκτούμε χάρις στη Φιλότητα (θυμηθείτε επίσης να του τα προσφέρετε οπωσδήποτε).

Έτσι, το αίτημα της Παιδείας είναι διφυές: Και Εκπαίδευση (γνώσεις, δεξιότητες) και Καλλιέργεια (αισθητική καλλιέργεια, μύηση στην ηδονή του ήθους), μαζί με τις ικανότητες της εργατικότητας, της συνεργασιμότητας και της μεθοδικότητας. Από μια τέτοια Παιδεία αναμένονται η ευμάρεια και η ευτυχία του Ατόμου, καθώς και σπουδαίες συνέπειες για την Κοινωνία (Οικονομία, Τεχνολογία, Επιστήμη, Διαπροσωπικές σχέσεις, Τέχνη, Δικαιοσύνη, Κοσμοείδωλο). Πρόκειται για την πιο συμφέρουσα επένδυση.

Σπεύδω δε να θυμίσω ότι αυτό το τεράστιο (διά βίου μάλιστα) λειτούργημα της Παιδείας, δεν είναι δυνατόν να ασκηθεί στα στενά όρια των σχολείων όλων των βαθμίδων, αλλά απαιτεί την ολομερή συμμετοχή της Οικογένειας, της Κοινότητας, της Συνεχιζόμενης εκπαίδευσης και των Μαζικών Μέσων Επικοινωνίας.

Δεύτερον, από τη φύση και την έκταση του θεσμού της Παιδείας και των θεμελιωδών σκοπών της, είναι ολοφάνερο ότι η Παιδεία προορίζεται να βρίσκεται στο κέντρο της Πολιτικής (θεωρίας και πράξης). Και το αντίστοιχο υπουργείο (πρώτο τη τάξει) παρά τω Πρωθυπουργώ, με δυσαναλόγως μεγάλο αριθμό υφυπουργών, και με σχετικές παγκομματικώς αναγνωρισμένες ανεξάρτητες Αρχές. Γιατί; Μα διότι το αποτέλεσμα οποιασδήποτε νομοθεσίας Παιδείας θα κριθεί στην πράξη μετά από 15 χρόνια – ενώ μια κυβέρνηση διαρκεί 4 χρόνια, ο δε υπουργός 2 χρόνια συνήθως. Απ' αυτήν την άποψη, είναι κραυγαλέως παράλογο το αίτημα εφαρμογής μιας "κομματικής" πολιτικής στην Παιδεία. Η μεγάλη πάντως δυσχέρεια προέρχεται απ' την ενδεχόμενη πολιτική μυωπία μεγάλης μερίδας του Λαού μας, ο οποίος δεν συναινεί να χάσει τίποτα "σήμερα", έναντι ενός κέρδους που θα προκύψει μετά από "είκοσι χρόνια". (Και, φυσικά, αυτήν τη στάση είναι σχεδόν υποχρεωμένοι να υπηρετήσουν και οι κοινοβουλευτικοί του αντιπρόσωποι…)».

Πολλές αντιφάσεις...

«Πράγματι, ο μακρόπνοος σχεδιασμός της Παιδείας σκοντάφτει ανά πάσαν στιγμήν σε μέγα πλήθος αντιφάσεων. Και συγκεκριμένα:

– Αναγνωρίζοντας ότι τα κύρια γνωρίσματα του δημοκρατικού και αποδοτικού Πολίτη αποκτώνται μόνον στις τρυφερές ηλικίες, μήπως πρέπει να αναστρέψομε τα μεγέθη χρηματοδότησης Νηπιαγωγείων και Πανεπιστημίων;

– Πόση Καλλιέργεια, έναντι πόσης Εκπαίδευσης; Θέμα τεραστίων οικονομικών, κοινωνικών και πολιτικών διαστάσεων…

– Και πώς να υπηρετήσω τα λαϊκά συμφέροντα για μελλοντική τεχνολογική ανάπτυξη, απαιτώντας "εντατικοποίηση" απ' τη σημερινή γενιά των Μαθητών; Ποιος να διαπραγματευθεί, με ποιον;

– Τι θα κάνω με τις ειδικές ανάγκες μάθησης των παιδιών του κατώτερου και του ανώτερου άκρου του φάσματος του δείκτη ευφυΐας; Πολύτροπα αντικρουόμενα συμφέροντα…

– Πώς θα εξασφαλίσω την μέγιστη αποδοτικότητα του πολύτιμου διδακτικού προσωπικού στη Γενική Παιδεία, με απαιτητικότερες σπουδές, με συνεχή μετεκπαίδευση και αξιολόγηση – μαζί με διπλασιασμό των μισθών τους; Εδώ, ούτε καν ένας εκπρόσωπος του Συλλόγου Γονέων δεν επιτρέπεται να παρακολουθήσει ένα μάθημα…

– Πώς θ' αντιμετωπίσω την απεχθέστερη των κοινωνικών αδικιών, εκείνην ενώπιον της Παιδείας; Υποβαθμίζοντας τα κριτήρια εισαγωγής στην Τριτοβάθμια, με συνέπειες αρνητικές για την στάθμη των πανεπιστημιακών σπουδών – άρα και των λαϊκών συμφερόντων για Ανάπτυξη; Ή, ίσως, με αντιμετώπιση του προβλήματος "ανάντη", εκεί που γεννιέται – παρεμβαίνοντας έγκαιρα στον χώρο της οικογένειας, της κοινότητας και των σχολείων των υποανάπτυκτων περιοχών;

– Άραγε, θα ακολουθήσω φιλολαϊκή πολιτική αυξάνοντας το πλήθος των πανεπιστημιακών πτυχιούχων – καταδικάζοντας δηλαδή ένα μεγάλο ποσοστό τους στην ανεργία ή στην άσκηση άσχετων συνήθως επαγγελμάτων; Ή, μήπως, προβλέποντας εγκαίρως αυτήν την αναπόφευκτη συνέπεια και στήνοντας μια ρωμαλέα δημόσια Επαγγελματική Εκπαίδευση, θα υπηρετήσω έτσι διπλά τα λαϊκά συμφέροντα (αφού συγχρόνως θα έχω προσφέρει και πολύτιμα στελέχη στην Οικονομία);

– Μπροστά στον συνεχώς αυξανόμενο όγκο των αναγκών Καλλιέργειας και Εκπαίδευσης, γιατί δεν επεκτείνω τη μαθησιακή διάρκεια, μέσω ενός εθνικού θεσμού Συνεχιζόμενης

Παιδείας ως αναγνωρισμένου και αφειδώς χρηματοδοτούμενου οργάνου δια βίου Παιδείας – ιδίως των φτωχότερων παιδιών που έχουν αδικηθεί;».

Έχουμε μάλλον σειρά αδιεξόδων, πολιτικών και άλλων, και τι μπορούμε να πούμε για αυτά;

«Όσοι τυχόν αναγνώστες σας, έφθασαν έως εδώ και δεν βαρέθηκαν, θα έχουν ίσως καλύτερα κατανοήσει την απέραντη περιπλοκή και τα οιονεί αδιέξοδα που εμπεριέχει το ενέργημα της Παιδείας: Αλλεπάλληλα διλήμματα οικονομικά και κυρίως αξιακά (δηλαδή, τελικώς, κοινωνικο-πολιτικά) παρουσιάζονται – το κυριότερο των οποίων (το ξαναλέμε) είναι ηθολογικού χαρακτήρα: Ποιος πείθεται να υποστηρίξει αποφάσεις με αβέβαιο αποτέλεσμα σε μακρόν χρονικό ορίζοντα, θυσιάζοντας άλλα βραχυπρόθεσμα συμφέροντά του; Και ποιοι (και κυρίως πόσοι) διαθέτουν τις εξαιρετικά ειδικευμένες γνώσεις για το πλήθος και το είδος των παραγόντων που διαρρέουν τους πολλαπλούς προβληματισμούς της Παιδείας; Και μία συναφής ερώτηση: Ξέρετε κανένα ελληνικό κόμμα που να έχει δημοσιεύσει την εθνικώς αναγκαία 500σέλιδη Λευκή Βίβλο της Παιδείας με τις αιτιολογημένες προτάσεις του κόμματος; Αυτή λοιπόν ήταν, νομίζω, η απάντηση στο ερώτημά σας πού οφείλεται το βήμα σημειωτόν στην Παιδεία μας, και γιατί όλοι οι 2ετούς διαρκείας αρμόδιοι υπουργοί στήνουν κι από μία δικιά τους "μεταρρύθμιση"…».

Πάντως ένα από τα θέματα συζήτησης των τελευταίων ημερών (για μία ακόμη φορά) είναι μια φιλολαϊκή και αναπτυξιακή επαγγελματική εκπαίδευση. Γιατί επί δεκαετίες δεν το έχουμε καταφέρει; Έχουμε την «πανεπιστημιοποίηση» των πρώην ανώτερων επαγγελματικών Σχολών, αλλά τελικά και την ανεπάρκειά τους.

«Ναι, μίλησα ήδη για την τάση να εφαρμόζομε μια δήθεν φιλολαϊκή πολιτική αυξάνοντας το πλήθος των εισαγομένων στην Τριτοβάθμια εκπαίδευση, με τα εξής τρία (σαφέστατα αντιλαϊκά) αποτελέσματα: Πρώτον, είναι τόσο μεγάλο το πλήθος των πτυχιούχων, που αντιλαμβάνονται ότι τους παγιδεύσαμε στην αναπόφευκτη ανεργία ή στην άσκηση άσχετων (χειρωνακτικών συνήθως) επαγγελμάτων. Δεύτερον, λόγω του πλήθους των φοιτητών της Τριτοβάθμιας, πέφτει αφεύκτως η στάθμη των σπουδών – άρα υποβαθμίζονται και τα αναμενόμενα για την Ανάπτυξη της χώρας αποτελέσματα. Και τρίτον, εις τούτο το μεταξύ η παραγωγή έχει στερηθεί πολύτιμα επαγγελματικά στελέχη, που θα τα ετοίμαζε μια δημόσια ρωμαλέα επαγγελματική εκπαίδευση, και θα τα ακριβοπλήρωνε η παραγωγή.

Αφήσαμε λοιπόν να ατονεί συνεχώς και συστηματικώς η επαγγελματική εκπαίδευση – στ' όνομα, λέει, της κοινωνικής δικαιοσύνης. Ταΐσαμε δηλαδή τον απληροφόρητο λαό μας με φούμαρα. Εν τω μεταξύ, η οικονομική πραγματικότητα εθεράπευσε και την παλαιότερη κοινωνική υποτίμηση των επαγγελματιών – όταν οι απολαβές τους τώρα έγιναν ασυγκρίτως ανώτερες απ' την ετεροαπασχόληση (ή και την ανεργία) των πτυχιούχων. (Εξ ου και η αίτηση διαζυγίου της νιόπαντρης που εξηπατήθη: "της είχε πει πως είναι Υδραυλικός, και αποδείχθηκε καθηγητής της Υδραυλικής").

Το κακό χρονολογείται από 50ετίας. Θα έπαιρνα το θάρρος να υποστηρίξω ότι η σχετική συνέντευξή μου στον "Οικονομικό Ταχυδρόμο" της 1 Δεκ. 1966 είναι επίκαιρη ακόμη και σήμερα. Κι όταν ο Ράλλης θέλησε το 1976 να μελετήσει τα πιθανά σενάρια των συνεπειών της 9χρονης υποχρεωτικής εκπαίδευσης (και μ' έστειλε το ΕΜΠ στο υπουργείο Παιδείας επί 3μηνον), στο βιβλίο που εκδώσαμε εξηγούσαμε ότι το ετήσιο κόστος της Επαγγελματικής Εκπαίδευσης ανά φοιτητήν, ξεπερνάει το 3πλάσιο του αντίστοιχου κόστους της Γενικής Παιδείας. Σε λίγο το κόστος θα το ρίχνανε, χάρις στο υποκατάστατο του μαυροπίνακα και σε φτηνούς Καθηγητές που δεν προέρχονταν απ' την Παραγωγή – αλλά δίδασκαν "έρευνα"…

Εν τω μεταξύ, οι Κουτόφραγκοι δυνάμωναν τις παραγωγικές επαγγελματικές τους σπουδές (αλλά εμείς είμαστε έθνος υπερήφανον).

Όμως υπάρχει ελπίδα: Απ' την κυρία Διαμαντοπούλου η οποία έναν μήνα προτού φύγει απ' το υπουργείο, μου είχε τηλεφωνήσει κάποια προχωρημένη νυχτερινή ώρα ("ελάτε να βοηθήσετε να αποκαταστήσουμε την Επαγγελματική Εκπαίδευση"), μέχρι το πρόσφατο πραξικόπημα της αθρόας πανεπιστημιοποίησης παντός ΤΕΙ – φαίνεται ότι ωρίμασαν οι συνθήκες γι' αυτήν τη Μεγάλη Μεταρρύθμιση. Για να διευκολυνθεί, προτείνω να οργανωθεί μια σειρά από "εκτός Πρακτικών και εκτός δημοσιογραφίας" προκαταρκτικές συσκέψεις ειδικευμένων στελεχών, συμπολίτευσης και αντιπολίτευσης. Καιροί γαρ ου μενετοί».

Έχετε μιλήσει για την «ηδονή του ήθους» που συμβάλλει στην ατομική και στην κοινωνική ευδαιμονία.

«Επιτρέψτε μου ν' αρχίσω από ακόμη νωρίτερα: Η σπουδαιότερη των "τεχνών", η Πολιτική, θεμελιώνεται πρώτον σε προτιμώμενες προτεραιότητες Αξιών, ερείδεται στην κοινωνική Αλληλεγγύη, ενώ στην περίπτωση των δημοκρατικών καθεστώτων (όπου κατ' αποκλειστικότητα και ασκείται) η Πολιτική νομιμοποιεί τη Συναίνεση – αντί για την πυγμαχία. Έτσι, η Πολιτική δεν είναι ενέργημα γνωσιακής κατηγορίας (ό,τι αποφαίνεται η επιστήμη είναι διακομματικών). Απ' την απλή ανάγνωση λοιπόν του ορισμού της αποδεικνύεται ότι η Πολιτική ανήκει στο βασιλειών της Ηθικής. Επομένως κάθε αντικοινωνικότητα πολιτών (= ανηθικότητα) υπονομεύει το κοινό Καλό, και διαστρέφει την Πολιτική. Ιδού λοιπόν γιατί το αίτημα για Ηθο-Παιδείαν, δεν αφορά το Κατηχητικό, αλλά την ίδια την πολιτική ζωή ενός τόπου. Όταν μάλιστα, για μια συγκεκριμένη χώρα διαθέτομε πολλούς αξιόπιστους δείκτες αντικοινωνικότητας αποφασιστικής μερίδας του Λαού της, τότε φαίνεται ακόμα σαφέστερη η ερμηνεία της κακοδαιμονίας της και η καθαρά πρακτική σημασία της Ηθοπαιδείας – με άμεσα ευεργετικές συνέπειες στην Οικονομία. Κι ας κάνομε μια παρένθεση εδώ, αναφέροντας μερικούς απ' τους δείκτες για τους οποίους έκαμα λόγον: Αξία σεβασμού του διπλανού σου, αποδοχή της δημοκρατικής αρχής της συναίνεσης, ποσοστό οδικών ατυχημάτων σε συγκρίσιμα οδικά δίκτυα, ποσοστό δωρητών οργάνων μεταμόσχευσης, ποσοστό ετεροδοσοληψίας (δωροδοκίας), ποσοστό συνωμοσιολογικών ερμηνειών, ενημερότητα περί των επικρατουσών απόψεων της Επιστήμης, αυτοτραυματικές "καταλήψεις" σχολείων, έμμονος δανεισμός εις βάρος των μελλοντικών γενεών, κ.λπ., κ.λπ.

Σε μια τέτοια (υποθετική) χώρα, ο Δαρβίνος θα είχε προβλέψει τη βαθμιαία καταστροφή της, αφού εκείνος είχε διαπιστώσει ότι "μόνον εκείνες οι ομάδες πρωτευόντων έχουν εξελικτικό πλεονέκτημα, όσες έχουν εσωτερική συνοχή" (δηλαδή ηθική).

Μπροστά λοιπόν σ' αυτήν τη θεμελιώδη σημασία του ατομικού και δημόσιου Ήθους προς όφελος των μακρόχρονων λαϊκών συμφερόντων, ημείς τι πράττομεν; Σπεύδω δε να θυμίσω ότι η Ηθοπαιδεία δεν συνίσταται σε μετακένωση Γνώσεων, αλλά ασκείται κυρίως: α) Με το παράδειγμα του γονιού, του δασκάλου, του κοινωνικού ήρωα, των σπουδαίων γεγονότων της Ιστορίας και εμβληματικών περιστατικών των Τεχνών. β) Με την άσκηση των μαθητών σε Αυτενέργεια Φιλότητας, μέσω συμβαμάτων (happenings) πραγματικών κοινωνικών γεγονότων. γ) Με καμπάνιες των ΜΜΕ, ιδίως των ηλεκτρονικών και των τηλεοπτικών μέσων, οι οποίες δεν θα έχουν διδακτικόν χαρακτήρα (άπαγε!), αλλά θα είναι υψηλής στάθμης παραγωγές – υπό τον όρο βέβαια ότι όλοι οι παράγοντες θα έχουμε αυθορμήτως επιστρατευτεί για τον σπουδαίο αυτόν πολιτικό και φιλολαϊκό σκοπό. Είναι πάντως προφανές ότι απαιτείται μια πολύ ενισχυμένη υπερκομματική πλειοψηφία για κάτι τέτοιο.

Θα πρόκειται βέβαια για μια φιλόδοξη μακροπρόθεσμη καλοοργανωμένη εκστρατεία, με πλήθος δυσκολίες και διλήμματα χρόνου και χρήματος. Υποστηρίζω όμως ότι η θεραπεία μας οφείλει να είναι συνεπής προς τη μόνη διάγνωση που ερμηνεύει σημαντικό μέρος απ' την έρπουσα υποανάπτυξή μας. Δεν είμαι καθόλου αισιόδοξος – αυτή όμως θα ήταν μια γερή, πραγματική Μεταρρύθμιση!».

(Παπαματθαίου Μάρνυ / ΤΟ ΒΗΜΑ, 26.09.2021, https://www.tovima.gr/2021/09/26/society/theodosis-p-tasios-kraygaleos-paralogo-to-aitima-kommatikis-politikis-stin-paideia)

Probabilistic tsunami forecasting for early warning

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Abstract

Tsunami warning centres face the challenging task of rapidly forecasting tsunami threat immediately after an earthquake, when there is high uncertainty due to data deficiency. Here we introduce Probabilistic Tsunami Forecasting (PTF) for tsunami early warning. PTF explicitly treats data- and forecast-uncertainties, enabling alert level definitions according to any predefined level of conservatism, which is connected to the average balance of missed-vs-false-alarms. Impact forecasts and resulting recommendations become progressively less uncertain as new data become available. Here we report an implementation for near-source early warning and test it systematically by hindcasting the great 2010 M8.8 Maule (Chile) and the well-studied 2003 M6.8 Zemmouri-Boumerdes (Algeria) tsunamis, as well as all the Mediterranean earthquakes that triggered alert messages at the Italian Tsunami Warning Centre since its inception in 2015, demonstrating forecasting accuracy over a wide range of magnitudes and earthquake types.

Introduction

Tsunamis may strike a coastal population close to the earthquake location within minutes after its origin time. Tsunami Early Warning Systems (TEWS) must forecast the tsunami threat rapidly following any potentially tsunamigenic earthquake. Tsunami impact prediction immediately after the event is subject to large uncertainty stemming mainly from the unknown details of the earthquake source, which implies large variability in the estimated tsunami inundation 1. The uncertainty is amplified by the necessity to act rapidly to maximize the evacuation lead time. Given the available information, a vast number of different forecast outcomes are possible. The forecasts should assign a probability to each of these outcomes (like in, for example, weather forecasting 2,3). Present-day tsunami forecasts are non-probabilistic, producing single-outcome forecasts. The uncertainty is often accommodated only implicitly through conservative choices (e.g. safety factors) to minimize missed alarms, at the cost of increasing the rate of false alarms 4. Supplementary Table 1 summarizes all the symbols and acronyms used.

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Testing PTF

To quantitatively test PTF performance for operational use in TEWS, we should define an unbiased set of events for which a tsunami warning issuance is required, regardless of whether a detectable tsunami was actually generated or not (the Gutenberg-Richter distribution of earthquake magnitudes implies that most of tsunami warnings will be issued close to this condition). To this end, we built a testing dataset (Fig. 5a) composed of all Mediterranean earthquakes that triggered alert messages from the CAT-INGV TSP, without any filter or selection. This includes all the twelve seismic events with initial magnitude estimate Mw ≥ 6.0 that occurred since CAT-INGV became operational in 2015. We added the 2003 Zemmouri-Boumerdes event, to enrich the set of events in the western Mediterranean, reaching a total of thirteen events (Fig. 5a). Observations for the tests include rapid and revised moment tensor estimates, and tsunami observations from the available tide-gauges and from run-up surveys, when available (more details in Supplementary Note 6).

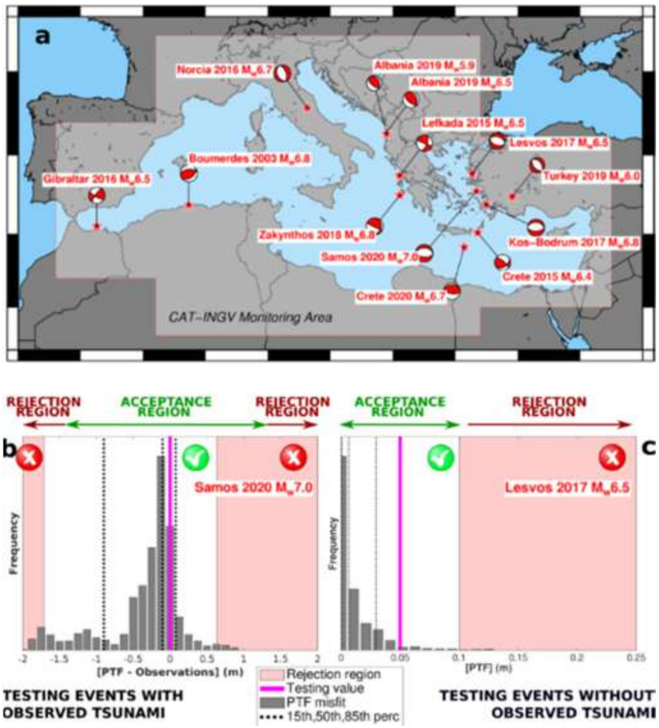

Fig. 5: Testing PTF.
a Testing dataset and monitoring area of CAT-INGV; additional details are reported in Supplementary Table 2. **b** Example of test for events with observed tsunami: the case of 2020 Mw 7.0 Samos-Izmir earthquake. PTF misfit distribution (*[PTF-Observations]*) is evaluated as the difference between near-coast wave amplitudes sampled from the PTF source ensemble and observations and staked for all observation points (see Methods). Gray bars report the misfit distribution, along with its 15, 50, and 85 percentiles (dashed lines). The model is rejected if the testing value (null misfit, purple line) falls in the rejection area (light red area); otherwise, the test is passed. **c** Example of test for events without observed tsunami: the case of 2017 Mw 6.5 Lesbos earthquake. The PTF distribution (*[PTF]*), obtained sampling from the PTF source ensemble, is expected to encompass small values. The model is rejected if the testing value (the 95th percentile of *[PTF]*, purple line) falls in the rejection area (light red area: near-coast wave amplitude < 0.1 m); otherwise, the test is passed. To keep spatial correlations, in both *[PTF-Observations]* and *[PTF]* the uncertainty in propagation is averaged (see Methods). All the other case studies are reported in Supplementary Figs. 4 and 5.

PTF accuracy is evaluated through formal hypothesis testing to assess the consistency between forecasts and available data and, if need be, to reject the PTF uncertainty model (see Methods). Both intermediate (source mechanism) and final (tsunami intensity) forecasts are tested. Results indicate that overall focal mechanism forecasts are accurate, such that the PTF source model is never rejected (results in Supplementary Table 7). Tsunami data and forecasts are compared simultaneously at all forecast points with observations, and spatial correlations are accounted for (see Methods). Although tsunami observations in many cases are limited, and sometimes with a poor signal-to-noise ratio due to the small event sizes, statistical tests confirm PTF accuracy also regarding tsunami forecasts, both for the events generating an observable tsunami (e.g. the October 30, 2020 Mw 7.0 Samos-Izmir event, Fig. 5b; results for all the six events of this type in Supplementary Fig. 4) and the ones for which a tsunami has not been observed (e.g. the 2017 Mw 6.5 Lesbos event, Fig. 5c; the results for all the seven events of this type in Supplementary Fig. 5). The tsunami generated by the Mw 7.0 Samos-Izmir earthquake (maximum run-up ~3.8 m104), as well as by the May 2, 2020 Mw 6.7 Ierapetra event, offered us a unique opportunity to perform a blind test for PTF, since the complete evaluation system was in place before the events occurred. The same test can be applied to the 2010 Maule tsunami, using both deep-sea and coastal observations as well as near-field and far-field observations; the results confirm the overall accuracy of PTF also for large magnitude event (Supplementary Fig. 4). On the other hand, for all the events that did not generate any measurable tsunami, PTF consistently forecasts an essentially negligible tsunami (<0.10 m) at all the observation points (Supplementary Fig. 5). While specific events may tend toward over/underestimation, altogether they pass the statistical test (accuracy level of 0.05). More details in testing results are discussed in Supplementary Note 7.

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Discussion

We present an approach dealing with uncertainty in real-time tsunami forecasting and linking alert-level definition for tsunami early warning to such uncertainty, coined Probabilistic Tsunami Forecasting (PTF). Current practices do not quantify uncertainty in tsunami forecasting and define alert levels deterministically. To reduce missed alarms, they typically adopt safety factors that increase the number of false alarms. PTF addresses this issue through explicit uncertainty quantification, linking alert levels to the desired level of conservatism.

This approach has been implemented for near-field tsunami warning and tested against all available data in the Mediterranean, including two blind tests (the recent 2020 Mw 6.7 Ierapetra and Mw 7.0 Samos-Izmir earthquakes), as well as for the 2010 Mw 8.8 Maule earthquake and tsunami, one of the largest events ever recorded. The results show that PTF is statistically accurate in its forecasts, ranging from relatively small crustal earthquakes to large magnitude subduction zone events.

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BIM: a game-changing technology?

What are the benefits of building information modelling and what is its role going forward?

It is widely accepted that digitalisation is a game-changing strategy that will empower the construction sector to thrive and deliver the expertise for sustainable energy skills.

That is the view of Paul McCormack, BIMCert programme manager at Belfast Metropolitan College in Northern Ireland.

McCormack believes that transforming the EU Construction Sector to be greener, consume less energy and to reduce the carbon footprint of the sector, will be driven by the growing market for digitalisation and data and by legislated carbon reduction targets but it will all be achieved through upskilling the built environment workforce. Building information modeling (BIM) is the backbone of the new 'informed' way of working triggered and targeted by the digitalisation opportunities presented to the sector.

A BIM model of the internal utilities of a building

"The challenge for industry is how to engage in the digitalisation journey, where is the nest starting point and how do you navigate a journey when you are unsure of the destination?" says Paul.

A BIM model of the internal utilities of a building.

"As with any journey it is vital that you get the fundamentals right. The digitalisation journey is no different, get the right training materials, suitably prepared and correctly packaged for the audience, ensure the learning process fits and is well mapped out.

A future-fit industry

"Whilst technology affords us the chance to do many things, it is essential to get the theory and practice right first. Ensuring the correct pedagogical structure for the process is the foundation of the learning process regardless of the delivery mechanism."

"In the post, Covid-19 crisis there will not be a return to pre-pandemic normality; many of the previous systems, structures and jobs have disappeared and will not return. It is therefore imperative that to help kick start the economy and to take full benefit from the emerging low carbon economy and other opportunities, all training tools, mechanisms and channels developed must be future fit in design, content, delivery and accreditation.

"In the current crisis individuals, industries and governments are being affected on an unprecedented scale in the current crisis. Our challenge is to develop training materials and modules for the new economy and marry these with new forms of learning. This approach enables industry and workers to start their digitalisation journey learning learn new skills whilst also accelerating the process." BIMcert is a project based upon three steps, aimed at providing a large-scale training & qualification scheme providing the requisite skills for the entire construction supply chain to:

1. Enable collaborative working to improve access to and the transition from design to development and delivery of both new build and renovation to achieve energy efficient near zero buildings (embedded energy)

2. Achieve efficient and effective ongoing management of the building in terms of energy and fabric (operational energy)

3. Use Building Information Modelling (virtual construction) as the enabling methodology and tool (sustainable energy)

"The construction sector is increasingly struggling with how to gather and se data in a co-ordinated fashion across the entire sector supply chain. By upskilling the workforce initially to master the digital fundamentals and then to utilise BIM to gather the data, the sector can then organise, store and extract value from the data, leading to greener construction and enabling net zero carbon footprints in construction. BIM is simply a repository of energy information of buildings, accessible and usable by all stakeholders in a systemic and coordinated environment," he continues.

"BIM is an enabler and a priority for companies to secure a basic grasp of, but in reality the level of knowledge and use of BIM will differ from one company to another depending on their position on the construction value chain. Whilst large multinational companies will have resources for a dedicated BIM department, SMEs will require this to be an 'add on' to someone's job description. Therefore, the BIM adoption levels, and development routes are different for each player and the resources available need to reflect this. Every company will adopt different BIM approaches depending on need and capacity. However, every company will require a basic grounding in BIM.

"Now is the time for companies to develop and implement their specific needs and opportunity driven digital strategy with BIM at the heart. The starting point for this journey is getting the fundamentals in place."

Building better together

Construction software specialist Trimble feels that the potential of BIM is often underestimated.

"Many people think of BIM as a digital formula for producing rich designs and visualisations. BIM is a lot more than just a better way of modelling objects, components and structures. From the earliest days of its inception, the aims of BIM were no less than to transform construction and the ways construction stakeholders work together in the actual building process, not just the design phase.

"BIM methodology allows the construction process to start before the design is ready. When the contractor has access to design data in the early phases and can interact and give feedback to the design team, a two-way interaction develops between design and construction which improves the project progress, planning and reduces rework."

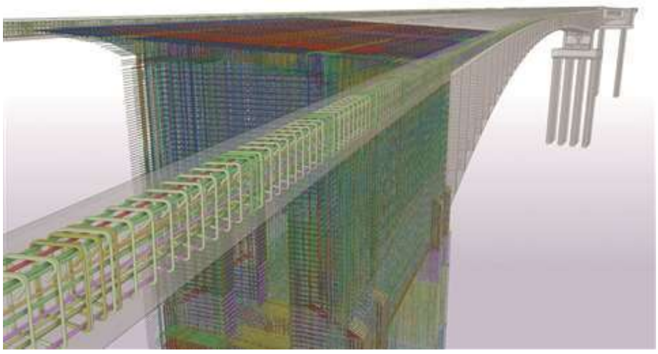
One thing that Trimble has noticed in the context of BIM is how construction has changed in recent years.

"The entire construction process has become much more information-driven, which is why our strategy is centered around the concept of 'constructible data.'

Working with shared and coordinated construction data enables all stakeholders to have the information they need to succeed and to ensure other stakeholders on a project also have what they need. The idea is to identify and solve issues related to physical construction up front and digitally with as much detail as possible. BIM means a project has multiple federated models (from architecture, layout, structural engineering,) that are shared so different project stakeholders can better coordinate as a team, which leads to meaningful improvements to delivery of the completed project.

Construction software specialist Trimble believes the potential of BIM is underestimated.

According to Trimble, analysis run on BIM and non-BIM projects in Norway shows that one of the obvious benefits is that when the BIM design process is run in a shared environment, with a continuous cross domain check, there is a significant reduction in the number of conflicts between domains. Also, when work in the field is connected to the office, for instance, project progress can directly inform project managers and even the accounting systems. Studies have shown that the costs of rework in construction can be up to 25% of the contract value and 10% of the total cost of the project, often due to management, planning, and communication issues. Integrating the field and the office in a connected project makes it easier for crews on site to better understand the designer's intent, which in turn can reduce errors.



Adopting BIM is seen as a key strategy for construction businesses emerging from the Covid-19 pandemic.

Another quality and efficiency step, says Trimble, is when construction machinery is connected to the model that is always up to date. The company has seen examples of utilizing constructible models to guide layout and fabrication workflows with robotic total stations and directly guiding earthmoving equipment through machine control. When the machines in the field are equipped with 3D-machine control, a huge benefit can be gained from directly connecting to the model to get the right design and the updates in real time and feeding back real time data while they execute. Therefore, it is not just important to work with BIM but in an open BIM environment that allows collaboration between several technologies.

Getting it right first time

Fabio Ponzio, vice president, building solutions at Hexagon's Geosystems division, says his company has various solutions supporting the lifecycle of BIM as well. For example, Scan-to-BIM, the process of digitally capturing an existing building or construction site with 3D laser scanning technology, can be used to create a BIM model of an existing building.

Scan-to-BIM contributes to time and cost savings by increasing the speed of accurate data collection. It also positively affects workers' safety by allowing them to remain at a distance while digitally capturing complex areas and environments. Deploying 3D laser scanning solutions and software also leads to less rework, as inaccuracies are avoided at the initial planning stage instead of being incorporated into the project itself — which will cause problems later.

"Having a visual model or digital twin also means that everyone involved in the project can understand and explore the site without making visits — resulting in a decrease in machine use and harmful CO_2 emissions and the number of face-to-face interactions as we continue to emerge from the pandemic. The collaborative BIM process also allows everyone on the team to work from the same detailed and accurate information source, making problems easier to identify and faster to resolve.

"As the construction industry emerges from the global pandemic, digital solutions that connect sites and teams easily and quickly will be key, including adopting BIM throughout the construction process".

To be fast and accurate

Asked whether BIM is currently seen as a contract-winning tool for large contractors, or whether it is now better understood and being used to greater purpose within both the tier one and SME community, Ponzio says he believes geography is an important factor.

"BIM adoption varies regionally. Some countries are further ahead as BIM has been mandated by the government. Still, many architects, engineers and contractors are using more traditional CAD methodology as well. Many companies are using CAD and BIM depending on the project. We see smaller and bigger companies adopting BIM and investing in tools like reality capture for Scan-to-BIM workflows.

"For example, in Spain, Sertogal SL used the Leica Geosystems' reality capture solutions to create a BIM model that guided the remodeling and expansion of the electrical substation of Mera in the province of Ourense — part of an ambitious initiative to partly absorb the energy production generated by 17 new wind farms planned in the region. In the Netherlands, engineering firm BIM4ALL, a member of the Brevo Group, was commissioned to document sewer pits across the whole country — around 10% of 80 million of these in need of replacement due to corrosion from hydrogen sulfide gas. To achieve this, BIM4ALL deployed the Leica RTC360 3D laser scanner to document 5-metre-deep pits — capturing two million points per second; each pit only took 15 to 30 minutes to complete. Based on this scanning data, BIM4ALL can create accurate BIM models of existing conditions as well."

On track with BIM at Naples Central Station

Minnucci Associati engineering studio has produced a complete IFC - BIM model of the central train station of

Naples in Piazza Garibaldi with millions of objects containing detailed information, technical data sheets, structural/thermal data and much more, with the aim of optimising network rails' management, enhancement and maintenance.

The overall model, consisting of a federation of over 50 IFC models, has been uploaded on the usBIM.platform CDE, which allows you to view various models and objects associated to multiple documents, information and data.

The usBIMplatform enables the user to view such a complex model even with a normal browser, such as Google Chrome or Internet Explorer, etc.

In this specific case, it is possible to access the same model directly from the GIS Open BIM from the platform.

Immersive virtual reality experience

The experience of the immersive virtual reality takes place in a simulated environment, where users can interact with virtual features or items by using special equipment. Virtual reality systems introduce the viewer into completely new virtual scenarios.

The virtual effects are commonly created by special viewers, such as VR headsets. The spectator is given a complete feeling of reality and can look around the artificial scenario.

The dynamic integration between BIM architectural design and immersive virtual reality allows architects and designers to have a much better understanding of their project and, perhaps more importantly, improve communication and client collaboration. VR technology has truly impacted the design experience allowing the various stakeholders to take part to the digital model creation and maintenance process.

It follows an interaction with the client who can be directly involved in the decision-making process during the design phase, in terms of simple decisions such as furnishing or finishes selection or more demanding functional-architectural choices.

In addition to the BIM model of the Garibaldi station, a digital model of the Naples to Rome line has also been produced.

The model reached a high level of detail for each railway object inserted and the signage details, thanks to the possibility of assigning technical datasheet and other type of information to the IFC model objects.

(Steve Ducker / CONSTRUCTION EUROPE, 29 September 2021, https://www.construction-europe.com/news/BIM-a-game-changing-technology-/8015162.article?utm_source=Newsletter&utm_medium=Email&utm_campaign=Construction-Europe-6th-October-2021)

Controls on Post-Seismic Landslide Behavior in Brittle Rocks

Matthew J. Brain, Sebastian Moya, Mark E. Kincey, Neil Tunstal, David N. Petley, and Sergio A. Sepúlveda

Abstract

Earthquakes trigger widespread landsliding in tectonically active landscapes. The effects of strong ground shaking on hillslope stability persist into the post-seismic stage; rates of landsliding remain elevated in the years following an earthquake. The mechanisms that control the spatial pattern and rate of ongoing landsliding are poorly constrained, hindering our ability to reliably forecast how landscapes and landslide hazard evolve. To address this, we undertook a detailed geotechnical investigation in which we subjected representative rock samples to dynamic loading, simulating the effects of earthquake ground shaking on hillslopes of different configuration. Our results indicate that post-seismic hillslope strength is not an intrinsic rock property; rather, it responds to the amplitude of imposed dynamic loads and the degree of pre-existing shear surface formation within the rock. This path-dependent behavior results from differences in the character of fractures generated by dynamic loads of different amplitude, and the ways in which apertures are mobilized or degraded in subsequent (post-seismic) shearing. Sensitivity to dynamic loading amplitude is greater in shallow landslides in which shear surfaces are yet to fully form; such hillslopes can be strengthened or weakened by earthquake events, depending on their characteristics. In contrast, deeper landslides on steeper hillslopes in which shear surfaces have largely developed are less likely to display differences in behavior in response to dynamic loading because strain accumulation along pre-existing fractures is dominant. Our results demonstrate the need to consider path-dependent hillslope stability in numerical models used to forecast how landscapes respond to earthquakes and how post-seismic hazard evolves.

Plain Language Summary

Landsliding is more common in the months and years after an earthquake. Our understanding of why this happens is limited but likely results from earthquake weakening of hillslopes. The mechanisms causing this weakening are difficult to assess at the landscape scale using satellite imagery. An alternative approach to improve our understanding of the controls on rock strength after an earthquake is to subject rock samples to seismic shaking in laboratory conditions. We used a custom-built apparatus to subject rock samples to pressure conditions typical of those experienced in shallow and deep-seated landslides. We simulated ground shaking of differing intensity to assess whether the rock was weaker or stronger after the shaking stopped. In simulated shallow landslides, ground shaking intensity affected how the sample cracked. Less intense shaking weakened the rock, implying it is more likely to fail following an earthquake. Conversely, more intense ground shaking strengthened the rock by creating a very uneven sliding surface, suggesting it is less likely to subsequently fail. Simulated deeper landslides on steeper hillslopes did not weaken, displaying less sensitivity to ground-shaking intensity. Our findings improve understanding of how hillslopes respond to seismic shaking, assisting forecasts of how landscapes and hazard develop after an earthquake.

1. Introduction

Seismic ground accelerations trigger large numbers of landslides in tectonically active, mountainous landscapes (Keefer, 1984; Parker et al., 2011; Roback et al., 2018). These coseismic slope failures, and the resultant release of large volumes of sediment into steep mountain catchments, have a significant effect on the geomorphic evolution of seismically active mountain regions (Croissant et al., 2019; Fan et al., 2018; Wang et al., 2015). Earthquake-triggered landslides can also result in considerable loss of life, damage to critical infrastructure and socio-economic disruption (Nowicki Jessee et al., 2020; Robinson et al., 2018). It is therefore important to understand and, where possible, to forecast how hillslopes in seismically active landscapes respond to earthquake ground shaking (Malamud et al., 2004; Marc et al., 2016; Meunier et al., 2007).

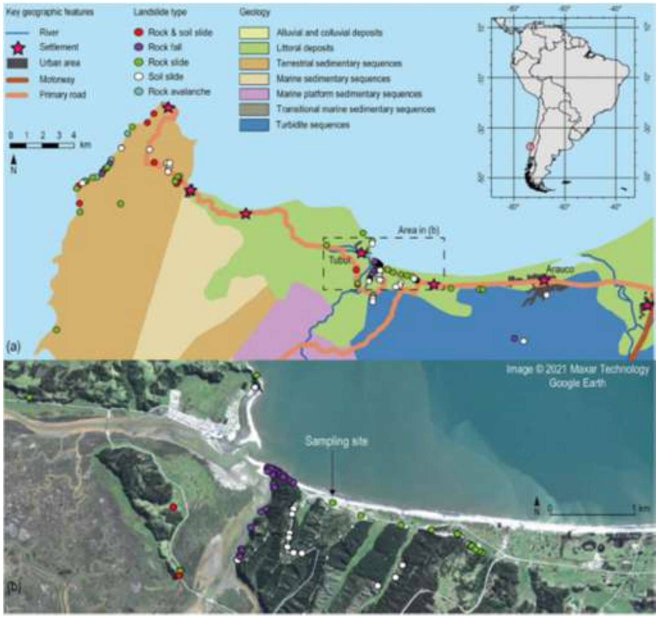
The effects of earthquakes on hillslope stability are persistent; regional rates of landsliding can remain elevated above background levels over annual to decadal timescales following the mainshock event (Hovius et al., 2011; Koi et al., 2008; Marc et al., 2015; Zhang et al., 2016). The mechanisms responsible for this temporal pattern are poorly constrained (Rosser et al., 2021). Transient, elevated (i.e., above rainfall-normalized baseline conditions) rates of post-seismic landsliding are not ostensibly controlled by external seismic or meteorological forcing (Marc et al., 2015) and have instead been attributed to a combination of erosion of regolith weakened by earthquake ground shaking (Fan et al., 2018; Kincey et al., 2021; Lin et al., 2008; Wang et al., 2015), and/or recovery of hillslope strength in the post-seismic phase following initial disturbance and weakening during ground shaking (Leshchinsky et al., 2020; Marc et al., 2015, 2021). The mechanisms responsible for the latter are poorly constrained but have been postulated to result from a range of "healing" processes that include the re-establishment of plant-root cohesion (e.g., Jacoby, 1997; Yunus et al., 2020) and the reversal of dilation experienced during an earthquake as rock and soil masses settle and re-establish frictional contacts (e.g., Lawrence et al., 2009).

However, isolating the dominant mechanisms, and combinations thereof, that control the post-seismic evolution of hillslope strength is not straightforward across landscapes characterized by considerable variations in geomorphic setting, landslide type and morphology (Fan et al., 2018; Hu et al., 2018; Kincey et al., 2021), and substrate lithology, rheology, structure and stress history (Bontemps et al., 2020; Brain et al., 2017; Carey et al., 2017, 2021; Gischig et al., 2015; Hu et al., 2018; Lacroix et al., 2014; Samia et al., 2017a; Viles et al., 2018). Both mapped landslide inventories and local field studies reflect landscape and landform response to a specific earthquake event (Rosser et al., 2021). As such, use of limited inventories does not allow us to explore how hillslopes respond to different mainshock stress paths and, hence, the range of behavior that hillslopes could potentially exhibit in the post-seismic phase. This is important to establish because the specific nature of earthquake ground accelerations (duration, amplitude, and frequency content) can itself exert a key control on the evolution of substrate strength and rheology in the post-seismic phase (Parker et al., 2015; Sepúlveda et al., 2016). Furthermore, we lack detailed understanding of how hillslopes of different configuration deform in the post-seismic phase in response to earthquake ground shaking of differing character. Hillslope angle and landslide depth, for example, set the baseline (aseismic) shear stress, strain, and damage conditions (Bieniawski, 1967; Brain et al., 2014; Eberhardt et al., 1999; Martin & Chandler, 1994; Petley et al., 2005) that are subjected to ground accelerations during an earthquake. Different combinations of ground shaking intensity and hillslope configuretion therefore have the potential to drive differences in post-seismic hillslope stability and/or behavior that are not captured in regional-scale mapping assessments (Marc et al., 2015).

The aim of this study is to determine how the intensity of ground shaking affects the post-seismic strength and rheology of rocks in hillslopes of different configuration and to constrain the mechanisms that cause any resultant variability. We used a novel geotechnical testing approach to subject samples of a single rock type to dynamic loads of varying amplitude to simulate differences in ground-shaking intensity in an earthquake mainshock. We then considered the effect of this dynamic loading on the subsequent deformation behavior of the rock, equivalent to the potential behavior of hillslopes in the post-seismic phase. We also explored if, how and why the baseline shear stress, a surrogate for hillslope angle, depth and, in turn, the degree of pre-seismic shear surface formation and damage, influenced the strength and rheology of the rock following dynamic loading, providing insight into the nature of hillslopes likely to experience elevated, or indeed reduced, susceptibility to post-seismic landsliding.

2. Rock Sampling Location

During the 2010 Mw 8.8 Maule earthquake, Chile (e.g., Delouis et al., 2010; Lorito et al., 2011), the Arauco Peninsula displayed elevated rates of landsliding, particularly in the sandstones and siltstones deposited in littoral settings during the late Pliocene and early Pleistocene (Escobar et al., 1982; Hackley et al., 2006; Melnick et al., 2009; Nielsen & Valdovinos, 2008; Serey et al., 2019). We obtained intact rock samples for laboratory analysis from the accessible coastal outcrops of the Tubul Formation on the Arauco Peninsula (Figure 1). In our sampling region, the well-drained and largely massive rock slopes experienced disrupted translational landsliding during the 2010 Maule earthquake (Serey et al., 2019; Verdugo et al., 2010). Initial reconnaissance indicated the failure depth at the site was approximately 5–10 m. Our specific sampling location was selected such that unsheared, intact rock samples were sufficiently distant from locations where hillslope failure and coseismic damage occurred.



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6. Conclusions

Using geotechnical laboratory testing, we considered how the strength and rheology of rocks can vary in the post-seismic phase in response to dynamic loading that varies in character. Our results indicate that post-seismic hillslope strength can be unchanged, increased or decreased relative to pre-seismic conditions.

This path dependence is controlled by the amplitude of dynamic loading experienced at a particular location and the degree of pre-existing shear surface formation within hillslopes, which is in part a function of landslide depth and hillslope angle. These factors govern the nature and location of fractures and asperities along incipient shear surfaces, and whether or not these are subsequently mobilized and/or degraded during post-seismic shear. More intact rocks, akin to shallow landslides (depth, $z \leq 5$ m) in field settings, are most likely to display divergent, path-dependent changes to strength and rheology in the post-seismic phase in response to seismic loading events of different amplitude. In more developed shear surfaces typical of deeper landslides ($z \approx 20$–30 m), dynamic loading is less likely to result in changes in post-seismic strength. However, dynamic loading causes enhanced asperity degradation, reducing the "critical strain" that landslides can sustain in the post-seismic phase. This has important implications for post-seismic assessment and forecasting of hillslope stability hazard.

Since the observed path dependence in hillslope behavior is a function of mechanisms common to brittle rocks, our findings are likely to be critical in a range of lithologies and seismic settings. In field locations, path-dependent behavior is likely to be manifest spatially in response to local to regionnal variations in landslide depth, hillslope angle and ground shaking intensity. Our findings add broader context and process understanding to regional scale datasets that consider the "recovery" of hillslope strength following earthquakes. Based on our results, and contrary to conclusions that may be drawn from synoptic regional-scale patterns, not all hillslopes will be more susceptible to failure in the post-seismic phase. Mechanisms of shear surface development and the specific nature of damage generated in different hillslope configurations and in response to ground shaking events of different character must be considered in assessments of post-seismic hillslope stability at a range of scales. Modeling path-dependent post-seismic hillslope behavior is an important next step in our ability to forecast how landscapes and landslide hazard evolve in the post-seismic phase over a range of spatial and temporal scales.

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The Archaeology of a Landslide: Unravelling the Azores Earthquake Disaster of 1522 and its Consequences

Christopher Gerrard, Paolo Forlin, Melanie Froude, David Petley, Alejandra Gutiérrez, Edward Treasure, Karen Milek and N'zinga Oliveira

The multidisciplinary research described here shows how archaeologists can help reconstruct past seismic episodes and understand the subsequent relief operation, rehabilitation, and reconstruction processes. In October 1522, a major earthquake and landslide struck the then capital of the Azores, Vila Franca do Campo, 1500 km from the European mainland. Damage was extensive, destroying key monuments, affecting most of the inhabited area, and leaving few survivors among the early colonists. The results from twenty-six archaeological trenches, geological and geoarchaeological investigations, and documentary analysis are reviewed here. Distinctive archaeological deposits are identified and explained, using the high density of artefacts and the erosional contact between the landslide and the pre-1522 palaeosol to reconstruct the episode in detail.

Introduction

On 22 October 1522, a powerful earthquake (magnitude 5.7–6.7) struck the island of São Miguel in the Azores archipelago (Carmo et al., 2013). Intense seismic shaking collapsed buildings over a wide area and triggered a major landslide in the hills above Vila Franca do Campo (Figure 1), the earliest and most important colonial settlement on the island. An estimated 3000 to 5000 lives were lost when a flow of mud and boulders swept through the coastal settlement and out into the sea; the event is still regarded as one of the most damaging natural disasters in European history. Most of what is known about medieval and early modern tectonic hazards and secondary hazards like landslides has been reported by historians and earth scientists (for an overview, see Guidoboni & Comastri, 2005; Ambraseys, 2009). Only a few field investigations for this period have had a specific archaeological focus (e.g. earthquakes at Basel in Switzerland in AD 1356: Fäh et al., 2009; Dyrrachium in Albania in AD 1270: Santoro & Hoti, 2014; landslides at Onoldswil in Switzerland in AD 1295: Akeret et al., 2018; volcanic eruptions and the AD 1343 Stromboli eruption: Rosi et al., 2019). These projects typically reconstruct events at a local or landscape scale and assess their magnitude or intensity, documenting loss of life and infrastructure, analyzing destruction deposits, and recording evidence for both community preparedness and disaster recovery. Even so, a detailed understanding of impact on the ground can be lacking (Ambraseys, 2006: 1009).

Vila Franca promised precisely dated archaeological deposits from early in the islands' documented history, the Azores being first claimed for Portugal in AD 1432, with permanent settlement taking place only after 1449 (Connor et al., 2012; Rull et al., 2017). In the context of a peripheral maritime community 1500 km from the European mainland, the responses and adaptions of colonists to environmental hazards were also of great interest (Gerrard & Petley, 2013; Forlin & Gerrard, 2017). Major landslides affect dense urban settings every few years worldwide. For example, there were an estimated 1765 casualties from the August 2010 Zhouqu landslide in Gansu in China, while the August 2017 landslide in Freetown, Sierra Leone, killed 1141 people, and two major landslides triggered by an earthquake claimed 2100 lives in the town of Beichuan in Sischuan province in China in 2018 (Yin, 2009). The removal of rubble, subsequent relief operations, and rebuilding activities can impede any understanding of the event and thus any estimation of future risk. Reconstructing what happened, even in modern settings, is challenging given the low rates of human survival and chaotic nature of the phenomenon. One way forward is to examine historic hazard events through archaeological excavation and field observation. That is the approach adopted here.

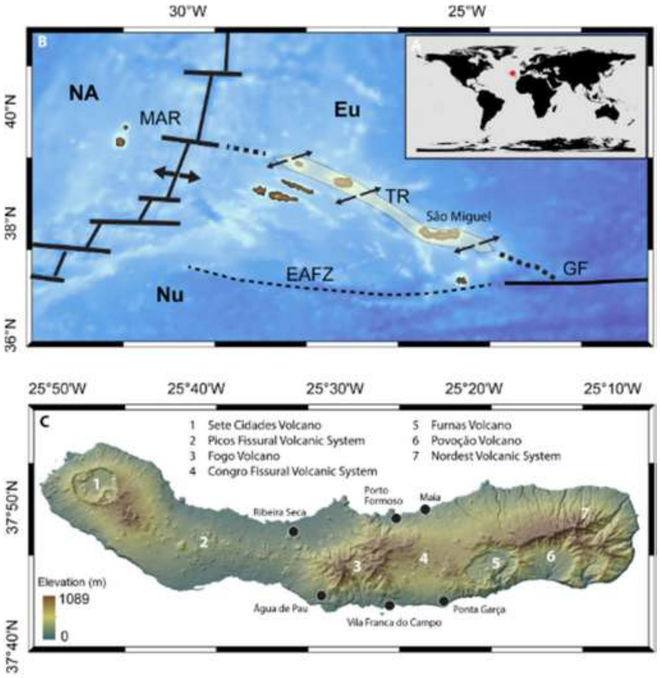

Figure 1. Above: location of the Azores (red dot) and São Miguel Island on the triple junction between the North American (NA), Eurasian (Eu) and Nubian (Nu) tectonic plates. Main structures: Mid-Atlantic Ridge (MAR), Gloria Fault (GF), East Azores Fracture Zone (EAFZ) and Terceira Rift (TR). Below: volcanic systems on São Miguel Island with the location of Vila Franca do Campo and other places mentioned in the text. *Figure by Melanie Froude and Alejandra Gutiérrez. Map adapted from Madeira et al., 2015 and Trippanera et al., 2014. World topography from NASA, 2018, bathymetry from NOAA, 2018, elevation from ALOS, 2018*.

Geological Setting

The Azores lie at the intersection of three major tectonic plates: the Eurasian plate on the north side, the African plate to the south and the North American plate to the west, with the Azores Microplate located at the junction (Figure 1). Marked by the Mid-Atlantic Ridge to the north and the Terceira Rift to the south, and the presence of a volcanic 'hotspot' with outpourings of basaltic magmas, this dynamic geological setting generates frequent volcanic eruptions and a high level of seismic hazard (Weiß et al., 2015, 2016).

All nine islands of the Azores have experienced destructive earthquakes (e.g. Terceira in 1614 (Farrica, 1980; Moreira, 1991) and São Jorge in 1757 (Machado, 1970; Farrica, 1980). Secondary hazards have proved especially damaging. At least a dozen tsunami events have been described over the last 500 years (Cabral, 2009), while on land the risk of landslides is amplified by steep valleys, unstable volcano-sedimentary rocks, and a wet maritime climate (for recent landslides see Marques, 2004; Marques et al., 2007). Over the past 5000 years, the island of São Miguel has experienced thirty eruptions at the Sete Cidades volcano, the Fogo volcanic complex, the Furnas volcano and along two basaltic fissure systems (Figure 1). Early colonists observed explosive activity and dome growth at Furnas in 1439–1443 (Queiroz et al., 1995), an event that is confirmed by geological evidence (Guest et al., 1999). In the centre of Ribeira Grande, the sixteenth Century "Pico de Queimada" fountain was buried under lava flows during an explosive eruption of sub-Plinian (i.e. with volume in the range of 0.05–0.50 km^3) scale at Fogo in 1563 (Wallenstein et al., 2015). There were further eruptions at Furnas in 1630, when some 200 people lost their lives in pyroclastic density flows (Cole et al., 1995), and in 1652 along the Picos Fissural Volcanic System (Ferreira et al., 2015). Volcanic sediments provide ample evidence for hazardous ashfall and flows of lava and mud. The presence of offshore collapse deposits (Weiß et al., 2016) indicates a major sector collapse of unknown age at Fogo to the south (Sibrant et al., 2015), similar to that on Mount St Helens (Washington, USA) in 1982.

Historical Sources and Previous Fieldwork

The Azorean priest and historian Gaspar Frutuoso (*c.*1522–1591) describes the 1522 earthquake and landslide in his account of the history and geography of the islands, *Saudades de Terra* (Frutuoso, 1998; see Rodrigues, 1991). This description, written fifty years after the event, is complemented by nine seasons of unpublished excavations between 1967 and 1981 by Manuel de Sousa d'Oliveira (Bento, 1989). The bulk finds from these campaigns, now in the Museum of Vila Franca, were reviewed and catalogued for our project; other materials are on display at the Fundação Doutor Manuel de Sousa d'Oliveira in Ponta Delgada. Unfortunately, Oliveira's excavation and recording methods do not now permit these artefacts to be linked to the stratigraphy. In addition, an important collection of almost complete pots was recovered in Vila Franca do Campo during the construction of the Centro Municipal de Formação e Animação Cultural in 1991 (Martins, 1996; Sousa, 2011: 84). These are said to belong to 1522 layers, but stratigraphic details are again absent, and the assemblage also includes later Portuguese tin-glazed wares. Among the finds is an intact rosette window carved in stone (93 cm in diameter), several stone grave markers and two copper-alloy candle holders (one intact, 38 cm high), all of which plausibly date to the sixteenth century.

More recently, Marques et al. (2009) undertook the first detailed sedimentological study of the 1522 landslide, establishing its depositional process and estimating its volume. In Vila Franca, the landslide deposit was found to lie above an ashfall deposit from Furnas C *(c.* ad 100) and capped by a thin layer of remobilized (reworked) material overlain by the ad 1630 ashfall deposit from the Furnas volcano (see for instance the profile of borehole VF45 on Figure 2). Without this research, there would have been no solid basis for further archaeological investigation.

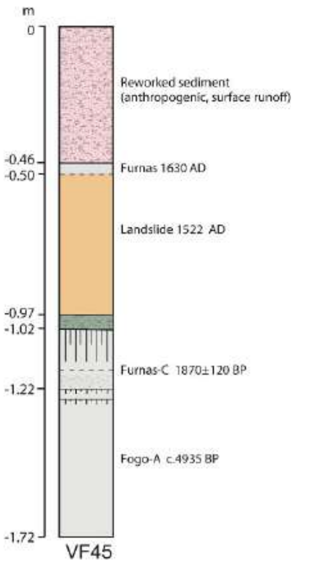

Figure 2. Stratigraphic profile from borehole VF45 of the geological context for the 1522 landslide. *(Redrawn by Melanie Froude and Alejandra Gutiérrez from Marques et al., 2009)*.

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The Landslide

Frutuoso recounts how the earthquake "broke away a great part of a hill at the foot of the mountain, which is above the town […] it swept everything before it, like thunder". This is a clear description of a high-mobility landslide. When the landslide reached the waterline it "took possession of the sea and entered it", generating a tsunami-type wave that damaged boats anchored about 700m off the coast (Andrade et al., 2006). Several survivors were swept into the water clinging to wooden planks and trees and even, in one case, a bed. One "very large boulder crossed the whole village from the hills to the sea […] where it came to rest in the old port […] entering the water for about forty paces" (all quotations from Frutuoso, 1998: Chapter 70).

Marques et al. (2009) identified a scar in the Ribeira da Mãe de Água river valley as one possible source of the landslide (Figure 3) and we can assume that the earthquake would have triggered multiple landslides there (Keefer, 1984). Frutuoso describes the land "running" downslope in many places, indicating that simultaneous co-seismic slope failures coalesced in the Ribeira channel into a single flow. Inspection of the 5m resolution digital terrain model (based on the 1:25000 scale topographic map by the Azores' Topography, Design and Cartography Division of the Regional Service for Housing and Equipment, DTDC-SRHE) in conjunction with Google Earth imagery, shows a distinctive concave slope approximately 500m in length with a semi-circular steep back scarp, which is likely to be a landslide scar. The composition of the landslide deposit is consistent with deposits of the Fogo A Plinian eruption (i.e. an eruption that generated columns of volcanic debris and hot gases) (Marques et al., 2009), which are estimated to be 5–10m thick at this location (Walker & Croasdale, 1971).

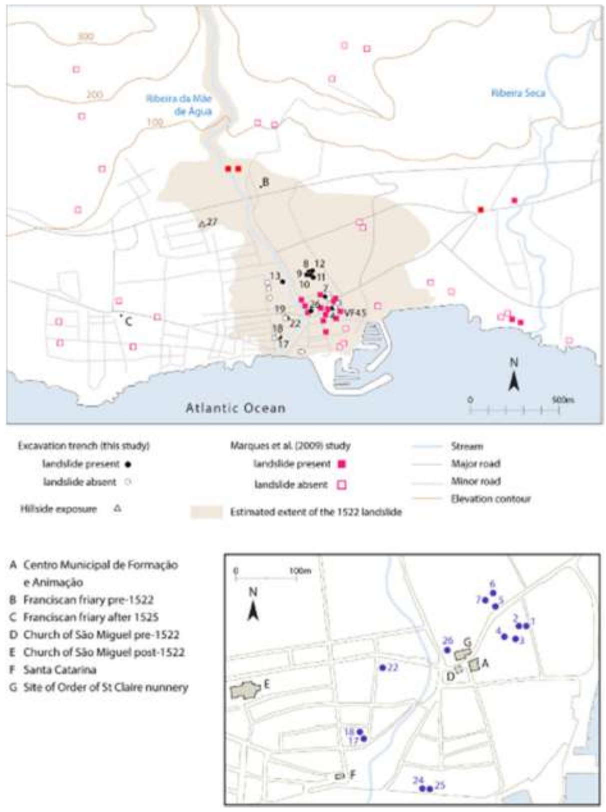

Figure 3. Above: location of excavation trenches and borehole investigations by Marques et al., 2009, indicating landslide presence or absence. Below: detail of the town plan locating places mentioned in the text and borehole VF45 (Figure 2).

Figure by Melanie Froude and Alejandra Gutiérrez. Elevation contours calculated from the ALOS, 2018 digital elevation model.

Marques et al. (2009) calculated that the landslide volume (including the coincident flow at Ribeira Seca) was 6.75 × 106 m^3. This is consistent with Frutuoso's description of a landslide 'flooding [the town] and covering it with earth, mud, and some large boulders from the northern side, completely sealing it'. The narrative suggests a 'flow-type' landslide concurrent with the earthquake, something which is commonly reported (Keefer, 1984, for example). The landslide scar lies on the edge of the Pleistocene Pico do Vento dome, formed from trachyte, an igneous rock extruded by the volcano. The crown (top) of the landslide is within a cinder cone (mapping by Carmo et al., 2015). A unit of igneous rock, formed as a flow, runs parallel with the scar, and there are outflow deposits (i.e. pyroclastic flow, pumice fall), an active spring, and fault near its base. The southern flanks of the Fogo volcano have many springs fed by perched aquifers confined by impervious geological layers (such as ash fall; Cabral et al., 2015). These geological structures provide suitable conduits and storage for groundwater, which may have enhanced instability in the hillslope and transformed it into a low cohesion 'debris flow', as defined by Varnes (1978).

Despite truncation or removal in some areas, we found evidence for the landslide in fourteen of our twenty-six trenches. Micromorphology from Trench 4 confirmed the deposit to be coarse and poorly sorted, with angular rhyolitic pitchstone gravel up to 2 cm in diameter embedded in a yellow-brown silt-loam (Supplementary Material 1 and 2). The overall fabric of the geomorphology sub-units (coded L2–L5 on Figure 5) was isotropic, indicating that clast orientation and dip were essentially random and consistent with a landslide deposit (see Supplementary Material 2). Some inhabitants were evidently outrun by the landslide, which implies that it must have been travelling at >2–3 m per second at that location; Frutuoso notes that 'the earth ran like waves of the sea', highlighting a pulse-like behaviour in which the deposit was laid down progressively, i.e. the sub-units L2–L5 represent subtle shifts in flow characteristic of a single event.

At the periphery of the debris fan in Hillside Exposure 27, the base of the landslide was scoured and mixed with the underlying Furnas C ash, indicating turbulence and pulses with higher water content. An erosional contact here is consistent with saturated flow, possibly involving liquefaction of the remobilized sediment. At its centre, on the other hand, the landslide deposit was thick with a consistent structure, vertically less heterogeneous with a near-horizontal erosional contact with the palaeosol. In Trench 4, this boundary was sharp but undulating (Supplementary Material 1 and 2; Figure 5) and the uppermost layer of vegetation, roots, and root channels had been scoured away. Gravel and pitchstone fragments of any size were completely absent from the original soil, but the uppermost 3 cm of sealed soil was perforated by numerous pitchstone gravel pieces from the landslide deposit, which had been pressed down into it when the surface was disturbed.

These physical characteristics have a crucial bearing on the interpretation of the archaeology. The horizontal erosional contact between the landslide and the palaeosol confirms that contexts predating 1522 were sometimes removed by the landslide and transported downslope. There is no 'intact' settlement waiting to be discovered beneath the main body of the landslide, as previous scholars have asserted (e.g. Ferreira, 1929).

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Conclusion

The archaeology of the Vila Franca earthquake and landslide in 1522 presents unusual interpretative challenges. Although the prospect of extensive, sealed deposits proved illusory and the body of the landslide itself contained unexpectedly little cultural material, a great range and density of objects were recovered where suitable contexts had survived—a signature feature of the archaeology of rapid-onset disasters. Of particular methodological interest was the large quantity of material incorporated into the "toe" of the landslide, where cultural layers had been pushed downslope. These near in situ assemblages are arguably more representative of daily life than more typical archaeological contexts in which artefacts and ecofacts have been selectively discarded in middens and pits. They represent "a moment in time" and offer invaluable clues to life at an early date in the economic and social development of the islands.

At first glance, the obvious comparison for the case study presented here might be the Great Lisbon earthquake and tsunami of 1755. That event sparked vehement debate about the divine character of destructive "natural" phenomena, beliefs which had themselves been formative to the response in Vila Franca 200 years earlier. There is an important difference, however. In Vila Franca, the greatest hazard that October night was the landslide not the earthquake tremors themselves; and, here, we hope to have provided new insight into how similar disasters in the future might affect buildings, and where victims might be recovered. Secondary hazards, especially landslides, are hugely neglected in the consideration of future earthquake events, despite the high toll that they frequently inflict.

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Timely prediction potential of landslide early warning systems with multispectral remote sensing: a conceptual approach tested in the Sattelkar, Austria

Doris Hermle, Markus Keuschnig, Ingo Hartmeyer, Robert Delleske, and Michael Krautblatter

Abstract

While optical remote sensing has demonstrated its capabilities for landslide detection and monitoring, spatial and temporal demands for landslide early warning systems (LEWSs) had not been met until recently. We introduce a novel conceptual approach to structure and quantitatively assess lead time for LEWSs. We analysed "time to warning" as a sequence: (i) time to collect, (ii) time to process and (iii) time to evaluate relevant optical data. The difference between the time to warning and "forecasting window" (i.e. time from hazard becoming predictable until event) is the lead time for reactive measures. We tested digital image correlation (DIC) of best-suited spatiotemporal techniques, i.e. 3 m resolution PlanetScope daily imagery and 0.16 m resolution unmanned aerial system (UAS)-derived orthophotos to reveal fast ground displacement and acceleration of a deep-seated, complex alpine mass movement leading to massive debris flow events. The time to warning for the UAS/PlanetScope totals 31/21 h and is comprised of time to (i) collect – 12/14 h, (ii) process – 17/5 h and (iii) evaluate – 2/2 h, which is well below the forecasting window for recent benchmarks and facilitates a lead time for reactive measures. We show optical remote sensing data can support LEWSs with a sufficiently fast processing time, demonstrating the feasibility of optical sensors for LEWSs.

How to cite.

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1 Introduction

Landslides are a major natural hazard leading to human casualties and socio-economic impacts, mainly by causing infrastructure damage (Dikau et al., 1996; Hilker et al., 2009). They are often triggered by earthquakes, intense short-period or prolonged precipitation, and human activities (Hungr et al., 2014; Froude and Petley, 2018). In a systematic review Gariano and Guzzetti (2016) report that 80 % of the papers examined show causal relationships between landslides and climate change. The ongoing warming of the climate (IPCC, 2014) is likely to decrease slope stability and increase landslide activity (Huggel et al., 2012; Seneviratne et al., 2012), which indicates a vital need to improve the ability to detect, monitor and issue early warnings of landslides and thus to reduce and mitigate landslide risk.

Early warning refers to a set of capacities for the timely and effective provision of warning information through institutions, such that individuals, communities and organisations exposed to a hazard are able to take action with sufficient time to reduce or avoid risk and prepare an effective response (UNISDR, 2009). According to UNISDR (2006), an effective early warning system consists of four elements: (1) risk knowledge, the systematic data collection and risk assessment; (2) the monitoring and warning service; (3) the dissemination and communication of risk as well as early warnings; and (4) the response capabilities on local and national levels. Lead time as defined in the context of landslide early warning systems (LEWSs) is the interval between the issue of a warning (i.e. dissemination) and the forecasted landslide onset (Pecoraro et al., 2019) and thus crucially depends on time requirements in phases (1)–(3). The success of an early warning system (EWS) therefore requires measurable pre-failure motion (or slow slope displacement) to allow for sufficient lead time for decisions on reactions and countermeasures (Grasso, 2014; Hungr et al., 2014).

While remote sensing has been established for early warnings, remote sensing is not yet used for real early warnings of the onset of landslides in steep alpine terrain (with a few exceptions), where geotechnical instruments are still preferred. Exceptions include terrestrial InSAR (Pesci et al., 2011; Walter et al., 2020) and terrestrial laser scanning with high repetition rates. However, repeated UAS (unmanned aerial system) and optical satellite (PlanetScope) images with high repetition rates have so far not been applied for landslide early warning in steep alpine catchments. In this regard, knowledge of sensor capabilities and limitations is essential, as it determines which rates and magnitudes of pre-failure motion can potentially be identified (Desrues et al., 2019). Our proposed framework refers to mass movements in steep alpine catchments with significant pre-failure motion over sufficient time periods and thus excludes instantaneous events triggered by processes such as heavy rainfalls or earthquakes.

This study presents a new concept to systematically evaluate remote sensing techniques to estimate and increase lead time for landslide early warnings in these catchments. We do not start from the perspective of available data; instead, we define necessary time constraints to successfully employ remote sensing data to provide early warnings. This approach reduces to a small number the suitable remote sensing products with high temporal and spatial resolutions. With these constraints, we investigated the application of data from satellites and UASs to allow the assessment of the data, after a spaceborne area-wide but low-resolution acquisition, into a downscaled detailed image recording. In so doing, we analysed the capability of these different passive remote sensing systems focusing on spatiotemporal capabilities for ground motion detection and landslide evolution to provide early warnings.

Recently, the spatial and temporal resolution of optical satellite imagery has significantly improved (Scaioni et al., 2014) and has allowed substantial advances in the definition of displacement rates and acceleration thresholds to approach requirements for early warning purposes. This is essential since the spatial and temporal resolution determine whether landslide monitoring is possible with the detection of displacement rates and approximate acceleration thresholds, both of which are lacking if information is based solely on post-event studies (Reid et al., 2008; Calvello, 2017). Landslide monitoring offers the potential to significantly advance LEWSs (Chae et al., 2017; Crosta et al., 2017). Previously, high-spatial-resolution satellite data were obtained at the expense of a reduction in the revisit rates (Aubrecht et al., 2017). Consequently, the return period between two images increased, limiting ground displacement assessment and the range of observable motion rates. The number of useful images was further reduced due to natural factors such as snow cover, cloud cover and cloud shadows. High-resolution remote sensing data were long restricted due to high costs and data volume (Goodchild, 2011; Westoby et al., 2012). Today commercial very high resolution (VHR) optical satellites exist, but tasked acquisitions make them inflexible and very cost intensive, thus limiting research (Butler, 2014; Lucieer et al., 2014). There is a vast spectrum of available remote sensing data with a high spatiotemporal resolution (Table 1). Complementary use of different remote sensing sources can significantly improve landslide assessment as demonstrated by Stumpf et al. (2018) and Bontemps et al. (2018), who draw on archive data and utilise different sensor combinations to analyse the evolution of ground motion.

Table 1 Overview of different optical multispectral remote sensors with their corresponding resolution [m] and revisit rate [d]. The sensors are categorised into commercial and free data policy. Source: ESA (2020).

Sensor	Temporal resolution [d]	Spatial resolution [m]	Free/ commercial
UAS	flexible	0.08	F[f]
WorldView-2	1.1	1.84	C
WorldView-3	<1	1.24	C
WorldView-4	<1	1.24	C
GeoEye-2	5	1.24	C
SkySat	1	1.5	C
GeoEye-1	3	1.64	C
Pléiades-1A/Pléiades-1B	1	2.0 (0.5)[e]	C
PlanetScope	1	3.0/3.125[b]	C/F[a]
RapidEye[c]	5.5	5[d]	F
Sentinel-2A/Sentinel-2B	5	10	F
Landsat 8	16	30	F

[a] Free quota via Planet's Education and Research Program. [b] PlanetScope Ortho Scene product, Level 3B/Ortho Tile product, Level 3A (Planet Labs, 2020b). [c] Reached end of life, March 2020, archive data usable. [d] Ortho Tile Level 3A, 5 m (Planet Labs, 2020a). [e] Colour pansharpened, 0.5 m. [f] Self-acquired.

The latest developments in Earth observation programmes include both the new Copernicus Sentinel fleet operated by ESA and a new generation of micro cube satellites, sent into orbit in large numbers by Planet Labs, Inc. These micro cube satellites, known as "Doves" as part of PlanetScope (from now on referred to as PlanetScope satellites), and Sentinel-2A and Sentinel-2B offer very high revisit rates of 1–5 d and high spatial resolutions of 3 and 10 m, respectively (Table 1), for multispectral imagery (Drusch et al., 2012; Butler, 2014; Breger, 2017). These high spatiotemporal resolutions open up unprecedented possibilities of studying a wide range of landslide velocities and natural hazards through remote sensing. Continuing data access is fostered by Planet Labs and by Copernicus (via its open data policy) providing affordable or free data for research. Examples of landslide activity studies employing multi-temporal datasets based on this access to high-spatiotemporal-resolution data include Lacroix et al. (2018), using Sentinel-2 scenes to detect motions of the Harmalière landslide in France, and Mazzanti et al. (2020), who applied a large stack of PlanetScope images for the active Rattlesnake landslide, USA.

As landslides tend to accelerate beyond the deformation rate observable with radar systems before failure, we concentrate on optical image analysis (Moretto et al., 2016). One advantage of optical imagery is its temporally dense data (Table 1) compared to open data radar systems with a sensor repeat frequency of 6 d and revisit frequency of 3 d at the Equator, about 2 d over Europe and less than 1 d at high latitudes (Sentinel-1, ESA). Optical data allow direct visual impressions from the multispectral representation of the acquisition target and the option to employ these data for further complementary and expert analyses. While active radar systems overcome constraints posed by clouds and do not require daylight, data voids can be significant due to layover or shadowing effects in steep mountainous areas (Mazzanti et al., 2012; Plank et al., 2015; Moretto et al., 2016). Moreover, north-/south-facing slopes are less suitable and thus limit the range of investigation (Darvishi et al., 2018). In general, sensor choice depends on the landslide motion rate with radar at the lower and optical instruments at the upper motion range (Crosetto et al., 2016; Moretto et al., 2017; Lacroix et al., 2019).

However, a flexible, cost-effective alternative to spaceborne optical data is airborne optical images taken by UASs. Freely selectable flight routes and acquisition dates enable avoiding shadows from clouds and topographic obstacles as well as unfavourable weather conditions and summertime snow cover, all of which frequently impair satellite images (Giordan et al., 2018; Lucieer et al., 2014). UAS-based surveys provide accurate very high resolution (a few centimetres) orthoimages and digital elevation models (DEMs) of relatively small areas, suitable for detailed, repeated analyses and geomorphological applications (Westoby et al., 2012; Turner et al., 2015).

In recent years, data provision for users has increased, and today data hubs provide easy accessibility to rapid, pre-processed imagery. Nonetheless, technological advances can be misleading as they promise high-spatiotemporal-resolution data availability, which frequently does not reflect reality (Sudmanns et al., 2019). One key problem is the realistic net temporal data resolution which is often significantly reduced due to technical issues, such as image errors and non-existent data (i.e. data availability, completeness, reliability). Other problems include data quality and accuracy in terms of geometric, radiometric and spectral factors (Batini et al., 2017; Barsi et al., 2018). Knowledge of the most useful remote sensing data options is vital for complex, time-critical analyses such as ground motion monitoring and landslide early warning. Timely information extraction and interpretation are critical for landslide early warnings, yet few studies have so far explicitly focused on time criticality and the influence of the net temporal resolution of remote sensing data.

In this investigation we both propose a conceptual approach to evaluating lead time as a time difference between the "time to predict" and the "forecasting time" and assess the suitability of UAS sensors (0.16 m) and PlanetScope (3 m) imagery (the latter with temporal proximity to the UAS acquisition) for LEWSs. For this we have chosen the Sattelkar, a steep, high alpine cirque located in the Hohe Tauern Range, Austria (Anker et al., 2016). We estimate times for the three steps: (i) collecting images, (ii) pre-processing and motion derivation by digital image correlation (DIC), and (iii) evaluating and visualising. The results from the Sattelkar site – and from historic landslide events – will be discussed in terms of usability and processing duration for critical data source selection which directly influences the forecasting window. Accordingly, we try to answer the following research questions:

1. How can we evaluate lead time as a time difference between the time to predict and the forecasting time for high-spatiotemporal-resolution sensors?
2. How can we quantify "time to warning" as a sequence of (i) time to collect, (ii) time to process and (iii) time to evaluate relevant optical data?
3. How can we practically derive profound time-to-warning estimates as a sequence of (i), (ii) and (iii) from UAS and PlanetScope high-spatiotemporal-resolution sensors?
4. Are estimated times to warning significantly shorter than the forecasting time for recent well-documented examples and able to generate robust estimations of lead time available to enable reactive measures and evacuation?

2 Lead time – a conceptual approach

2.1 The conceptual approach

Natural processes and their developments constantly take place independently, thus dictating the technical approaches and methodologies researchers can and must apply within a certain time period. For that reason, we hypothesise the forecasting window $t_{external}$ is externally controlled; consequently the applicability of LEWS methods ($t_{internal}$) is restricted because they must be shorter than $t_{external}$. This approach is the framework of our time concept (Fig. 1).

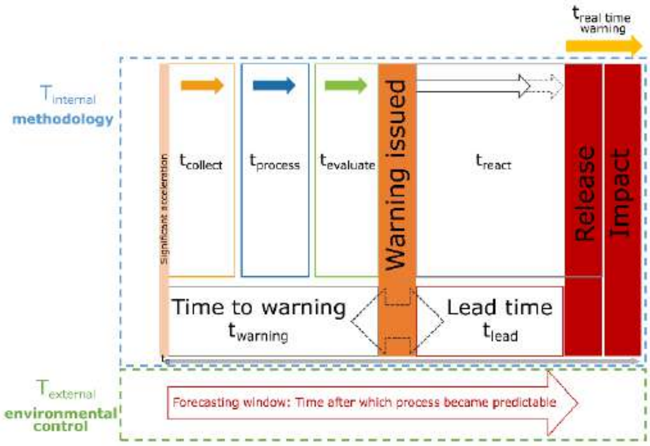

Figure 1f The novel conceptual approach for lead time, time to warning and the forecasting window for optical image analysis.

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https://nhess.copernicus.org/articles/21/2753/2021/

Catoca mine in Angola – using satellite imagery to understand recent events

According to Wikipedia, Catoca mine in Angola is the fourth largest diamond mine in the world. Located at -9.399, 20.301, it consists of a big open cast pit and a very large tailings storage area.

Last month, CRREBaC released information about a set of very significant pollution events in the rivers of Angola and Congo, linked to mining in Angola. Reports have included the pollution of hundreds of kilometres of the river system, deaths of fish and hippos and, in some cases, suggestions of up to twelve fatalities. Detailed information to evidence these huge losses is lacking, but there is little doubt that serious pollution occurred.

Whilst this blog is about landslides, I have very often written (and indeed campaigned) about the scandalously poor management of tailings in the mining industry, and I have highlighted several major tailings dam failures. My interest in the events in Angola and Congo results from concerns that the events might have been one or more tailings dam collapses.

One of the candidate sites for the events in Angola is the facility at Catoca, and indeed the operators have reportedly admitted that a release did occur, but only of water and sand.

This is a satellite image of the Catoca facility collected by Planet Labs on 21 July 2021:-

The Catoca diamond mine on 21 July 2021.

The pit is in the bottom right hand corner, the tailings facility in the huge orange area on the left side of the image. The tailings dam is located just above the centre of the image, orientated NNW-SSE. There is no evidence of any problem in this image.

The first sign of change appears in the image of 24 July 2021. The change is subtle but significant:-

Pollution downstream of the Catoca diamond mine on 24 July 2021.

I have put a black circle around some clear pollution on the downstream side of the tailings dam. Note that the tailings dam was intact (and remains so). A day later the problems had become very much worse:-

Pollution downstream of the Catoca diamond mine on 25 July 2021.

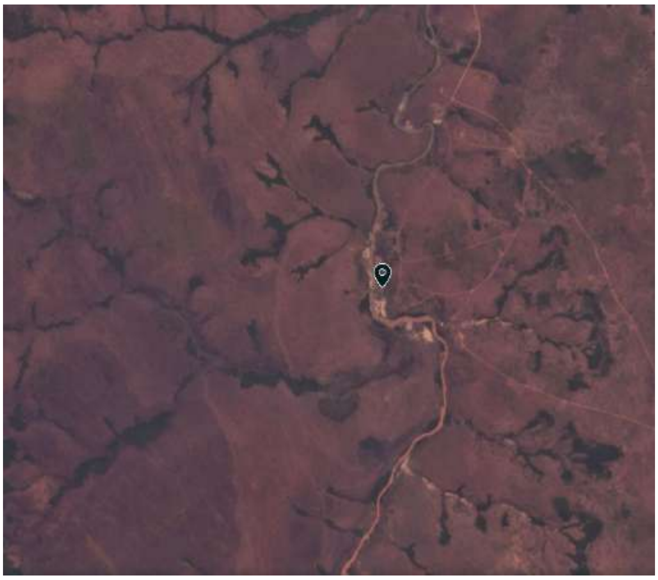
By 25 July 2021 a large plume of pollution had appeared on the downstream side of the tailings dam (highlighted with a circle again). The had entered the watercourse, which was now showing very clear signs of pollution (highlighted with an arrow).

The situation today, a few weeks later, is interesting:-

Pollution downstream of the Catoca diamond mine on 5 September 2021.

The plume has developed considerably, although it has not enlarged significantly (black circle). The polluted watercourse is very clear. There is clear evidence of works around the plume (new roads for example) and on the upstream side of the dam (white circle).

From the images above the pollution might not at first sight look serious, but satellite images downstream might tell a different story. This image was collected on 25 July 2021 at about 8:56 UT, downstream of Catoca at -9.127, 20.346:-



The front of the pollution downstream of the Catoca diamond mine on 25 July 2021.

The river is flowing from the south to the north. In the lower part of the image the river is bright orange with pollution. In the northern part of the image the river is unpolluted. The marker, at -9.127, 20.346 is the approximate front of the pollution moving downstream from Catoca. Note the profound change in the water as the pollution front moves through.

This is even more profoundly illustrated in the image below. The small tributary from Catoca flows in from the southwest. It meets the main channel, flowing from south to north. Note the huge change in water quality from this point onwards:-

The passage of pollution downstream of the Catoca diamond mine on 25 July 2021.

This location is -9.309, 20.362.

According to the New York Times article:-

In a statement last month, the company admitted that there had been a "rupture in the pipeline that works as a spillway."

The satellite images are consistent with this as the source of the pollution, although the ecological damage looks to be more severe than some have suggested.

However, there is an anomaly. The CRREBaC report indicates that substantial pollution was first seen in the rivers of Angola from 15 July 2021:

On the basis of the Sentinel images published by Visio Terra (Equipe Sentinel Vision, EVT919, 2021) and our preliminary investigations from riparian communities, this pollution has been observed since 15 July 2021 from the source in the Angola part of the basin and would have taken 15 days to reach the city of Tshikapa, and 21 days for the city of Ilebo in the Democratic Republic of the Congo (DRC).

The pollution observed on 15 July 2021 does not seem to have come from Catoca according to the images, which suggests a second serious event occurred in a different mine in the area.

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(Dave Petley / THE LANDSLIDE BLOG, 6 September 2021, https://blogs.agu.org/landslideblog/2021/09/06/catoca-mine-in-angola-using-satellite-imagery-to-understand-recent-events)

The Observational Method in Tunnelling

Diane Mather, Design Manager, Inland Rail, ARTC
Alex Gomes, Chief Technical Principal – Tunnels, SMEC

Background

The design of tunnels and underground structures often involves a myriad of technical disciplines, which can range from geosciences up to architectonics and electro-mechanics, depending on the tunnel purpose. However, because tunnels are invariably built within the ground, a naturally formed material is an inherent part of the tunnel structure, geotechnical engineering and structural design stand out as disciplines ubiquitous to most types of underground works, as they are necessary for the assessment of the ground and the ground-structure interaction.

While material properties and behaviour are better understood and can be more precisely modelled in structural mechanics, the ground is a complex material and geotechnical engineering is by far not an exact science. It must deal with the intrinsic limitations associated with the engineers' ability to explore the ground and determine its composition and properties, as well as with the constraints associated with the modelling and estimation of its behaviour during construction.

Due to these uncertainties, the tunnel designer must be cognisant that models and computation results should be understood as representing potential scenarios and outcomes, as opposed to being taken as precise predictions. In projects with complex sub-surface settings, anticipated ground conditions and response to excavation can only be confirmed once excavation is carried out. Hence, to achieve maximum economy and assurance of safety, a natural solution consists of the design of scalable engineering solutions that can be adjusted to encountered and observed conditions to meet the required performance criteria and safety levels.

The Development of the Observational Method

The suitability of the observational approach to deal with the complexity and unpredictability of ground and tunnelling engineering was identified by the early pioneers of rock and soil mechanics. Terzaghi (1943) initially suggested the "design-as-you-go" or "learn-as-you-go" method, which was further expanded and refined by Peck, who formally introduced the "observational method" as a rational strategy to deal with such uncertainties in his 1969 Rankine Lecture.

Since then, the observation method has evolved from relying purely on basic visual observations conducted on site to sophisticated procedures using modern monitoring instruments and computer-based back analysis techniques. It has become an essential element in the design and construction of underground works, especially when excavated through variable and complex geology, weak deformable rock masses and soils, and sections under very shallow or high overburden conditions. The observation method is a thorough planned methodology which is developed under a specific contractual framework to facilitate design changes during construction and provide a framework for risk management.

The CIRIA (1999) defines the observational method as follows:

"…a continuous, managed and integrated process of design, construction control, monitoring and review which enables previously-designed modifications to be incorporated during or after construction as appropriate. All these aspects have to be demonstrably robust. The objective is to achieve greater overall economy without compromising safety"

In Eurocode EC7 (EN1997-2004), the observational method is listed as one of the acceptable design methods. The use of this method can enable significant economy in particular circumstances and also be effective where estimation of geotechnical behaviour is difficult or uncertain.

The observational method requires effective and proactive response to actual encountered ground conditions and behaviour, as well as the performance of the prescribed designed ground support. This is achieved by developing (but not limited to) the following:

Employment of appropriately experienced tunnellers to undertake excavation of underground structures so critical observation can be continually made during excavation.

- Interpretation of geological conditions including its variability, key high-risk features and potentially most adverse -conditions.
- Design of ground support and estimated behaviour for representative conditions, including identification of controlling failure mechanisms.
- Objectives of the key parameters to be observed, measured and recorded during construction including high risk items (such as sensitive structures).
- Development of acceptable limits of behaviour (trigger action response plan) with pre-planned contingency response and or remedial actions, including clear responsbility of involved parties.
- Comprehensive instrumentation and monitoring plan, including a robust process of information collection, management and distribution.
- Evidence to confirm the quality of construction (support structures).

Caveats and Limitations

The observational method should not be used where there is insufficient time to fully develop and implement emergency plans or observations of actual ground support performance is difficult to obtain or is unreliable. For these cases, the CIRIA 185 recommends that the design should be based on robust assumptions with consideration of a factor of safety, in what is termed as "predefined design". While instrumentation and monitoring are still considered for performance validation, it is not used for design adjustments, but targeted at providing confidence to stakeholders that no undesirable event or adverse impact to adjacent infrastructure occur.

Project Implementation

Before construction starts, the possible behaviours must be assessed, acceptable limits of behaviour must be established, and an instrumentation and monitoring plan must be implemented to verify that the actual behaviour of the ground, the ground support and adjacent infrastructure is within acceptable limits. During construction, monitoring should be carried out as planned and assessed at appropriate stages, and planned contingency actions put into place if the limits of behaviour are likely to be exceeded.

While the monitoring of the ground and ground support behaviour is of utmost relevance, the assessment of the impact on adjacent and overlaying structures is also an integral part of verifying compliance with the project's contractual and stakeholder requirements. Instrumentation and monitoring allow the constructor to quantify the true impacts of construction, which in turn can assist in assessing any damage claims from third party property owners. It also provides assurance to third party infrastructure owners and other stakeholders that the impacts of construction are as estimated by the design and within acceptable limits.

During construction, ground conditions are generally assessed by a combination of face mapping and advanced exploration in the form of probe holes and use of geophysical methods. While access to the tunnel face is easy under a conventional cyclic excavation, it is not always possible when using a closed tunnel boring machine (TBM). In the latter case, data acquisition must rely more heavily on information obtained from the TBM operations and from advanced exploration ahead of the face.

Ground behaviour (or the ground response to excavation works) are typically assessed by correlating the observed ground conditions with design models, observation of natural phenomena and the interpretation of monitoring results considering potential failure mechanisms. This typically in-cludes the measurement of displacements (and sometimes also stress and strain) of the ground, ground support and adjacent infrastructure. During construction, results of geotechnical assessment and behaviour are continuously compared with the design assumptions and established trigger levels to identify the need for adjustments and/or implementtation of contingency measures.

Groundwater conditions are also a relevant aspect to be controlled and monitored, as the amount of water inflow and pressure encountered during construction may not only impact the ground and ground-structure behaviour but also lead to water-table draw-down and settlement that can impact adjacent infrastructure and the environment. During construction, ground treatment can be used at critical areas to mitigate groundwater inflow and consequential impact on the water table, especially in environmentally sensitive areas.

The proposed frequency of monitoring must consider the relative proximity and rate of construction. Monitoring frequencies should be continually reviewed so that the rate is appropriate in relation to the construction activity and the trends of the monitoring results. The requirements of Third-Party Agreements and planning approvals must also be adhered to in so far as they dictate monitoring frequency and the cessation of monitoring.

Review meetings provide an important forum where decisions on the works can be made based on the data received and the knowledge of ongoing site operations. The design of the monitoring system needs to indicate what would be an appropriate regime for routine review of data, taking account of actions which may follow from monitoring observations. This may include the specification of key outputs, such as summary graphs of key parameters which are to be produced on a regular basis.

Summary

The observation method is today an essential approach underlying the modern design, construction and risk management of tunnel and underground works, enabling cost or time savings, while maintaining an acceptable level of safety.

Whilst the application of the observational method must be scaled to the nature of the design and the perceived hazards and level of risk for each specific project, practically any tunnel project considers at least an instrumentation and monitoring plan to validate the design assumptions and observe potential impacts.

Stakeholders not familiar with the observational method may inappropriately associate it with uncomfortably low safety margins and project uncertainties, which may lead to cost and time overruns. A deeper scrutiny of the method shows however the contrary, as the observation approach includes the provision of a set of scaled solutions to the constructor, and a planned monitoring and design validation process that enable technical or contractual uncertainties to be addressed in a cost-efficient and safe basis.

As Australia currently experiences a boom in tunnel infrastructure projects and a new generation of engineers is introduced to the tunnel industry, it is vital that all stakeholders involved in tunnel engineering and tunnel projects become educated in the principles and application of the observational method, including not only technical disciplines, but also the commercial, juridical and managerial areas.

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The strange race to track down a missing billion years

A billion years have vanished from the geological record – and over 152 years after this was first discovered, scientists can't agree on why.

The paper was referring to an incident involving a motley team of explorers led by the one-armed, self-taught geologist John Wesley Powell. Their mission was simple, though not easy – to travel 1,000 miles (1,609km) downstream from the banks of the Green River in Wyoming, cataloguing their finds as they went.

It had been some weeks since anyone had heard from the party, and public anxiety was mounting. Now a man claiming to be the sole survivor was speaking to the press. The last time he had seen them, he said, Powell had been standing on his boat, waving his hat in cheery farewell... just before the whole expedition plunged directly into some deadly rapids. Hours later, the narrator had found a lone carpet-bag floating down the river. It contained Powell's notebooks.

In the week that followed, the tragic news was widely circulated. But Powell's own wife was not convinced – and it turned out she was quite right. It soon became clear that the source had probably never even met Powell, let alone accompanied the expedition. His whole story was entirely made-up.

Meanwhile, the explorers' continued on their journey, entirely unaware of the bizarre scandal unfolding back home. And soon afterwards, the living, breathing Powell uncovered a disappearance of a very different kind – a vanishing that would baffle geologists for the next century and a half.

The lost years

Two months earlier, Powell's team – an unusual assortment of trappers, suspected fugitives, Native American scouts, former editors and ex-convicts – had burdened four wooden rowing boats with everything they needed for their journey, including a number of sophisticated scientific instruments. With a crowd of well-wishers gathered around them, they raised their little American flag and pushed off into the rush of water below.

The trip would span 10 months and require no small amount of courage to complete. There were almost daily run-ins with swirling rapids, precipitous waterfalls, and threatening rocks, and at one point, Powell had to sprint away from a 20-ft (6m) wide flash flood of red mud. The team lost an oar mere hours after departing – and in just over two weeks, one of their boats had been swept away. In all, only six out of 10 members of the original party would return home.

The team first reached the Grand Canyon on 13 August 1869. By then, they had just a month's worth of rations remaining – some soggy apples, putrid bacon, musty flour and a sack of coffee – and many unknown dangers still lay ahead. The men were joking around as usual, but Powell wrote that to him "the cheer is sombre and the jests are ghastly".

At the time of the 1869 expedition, the Grand Canyon was a blank spot on Western maps – though of course local Native Americans knew it well (Credit: Alamy)

Even in these desperate times, the team were awed by a steady carousel of wonders. All around, there were grand spires, ornately carved buttresses, and strange, angular pinnacles – imposing scenery on the scale of giants. Of all this, Powell was particularly struck by the cliffs, which he later described as a "library of the gods" – a place where colourful layers of rock formed the "stony leaves of one great book", in which they could read, line by line, how the universe was made.

At least, this is how it seemed at first. But then Powell discovered something odd in the bewildering height of the canyon walls.

Standing at the base of the cliffs and looking upwards, he could see a thick section of hard, crystalline rocks – mostly granite and schist (slate or shale that has been subjected to intense pressure), arranged in unusual vertical layers. Above this was a 1,000ft (305m) band of reddish sandstone, in the neat horizontal lines you would expect.

But here was the catch – by counting the layers of vertical crystalline rock, Powell estimated that this section should be 10,000ft (3,050m) thick. In reality, it measured just 500ft (152m). There were thousands of feet of missing rock – it had just vanished. He named this feature The Great Unconformity, and asked himself, "how can this be?".

Today geologists know that the youngest of the hard, crystalline rocks are 1.7 billion years old, whereas the oldest in the sandstone layer were formed 550 million years ago. This means there's more than a billion-year-gap in the geological record. To this day, no one knows what happened to the rocks in between.

Rocks are usually laid down in a sequence of orderly layers, one on top of the other – but The Great Unconformity breaks with tradition (Credit: Alamy)

A global anomaly

While the missing rock is particularly obvious in the Grand Canyon, the phenomenon is ubiquitous.

"It's one of these features that pretty much occurs under a lot of people's feet, when they don't even realise it," says Stephen Marshak, professor emeritus in the Department of Geology at the University of Illinois. He explains that in the centre of any continent, whether you're in the United States, Siberia or Europe, if you drill down far enough you'll hit the two layers of rock involved in this mysterious geological anomaly.

"And so what that means is that everywhere beneath you, that boundary exists – sometimes it's close to the surface and you can see it, sometimes it's kilometres below the surface, but it's always there, except in mountain ranges where it's been stripped away entirely," says Marshak. "And so it's widespread, and it's telling us a very, very important story about the Earth history."

As Marshak alludes, finding out what happened during, and led to, the missing billion years is no trivial matter. There are two reasons for this. The first is that it just so happens to have occurred immediately before another inexplicable event – the sudden proliferation in the diversity of life on Earth 541 million years ago.

The Cambrian explosion refers to an era when the oceans suddenly shifted from hosting a scattering of weird and unfamiliar creatures – such as triffid-like leaf-shaped animals and giant steamrollered ovals which continue to defy all efforts to categorise them – to an abundance of life, with many of the major taxonomic groups around today. It happened in the space of just 13-25 million years – an evolutionary twinkling of an eye.

The problem was first identified in the 1840s, and proved to be particularly challenging for Charles Darwin. He called it "inexplicable" and lamented in On the Origin of Species "…the difficulty of assigning any good reason for the absence of vast piles of strata rich in fossils beneath the Cambrian system is very great".

The second is that it's thought Earth underwent radical climate change during the lost years – possibly turning into a giant ball of ice, with an almost entirely frozen surface. Very little is currently known about how this "snowball Earth" formed, or how life managed to cling on.

During the snowball Earth phase, which occured at least 650 million years ago, even the equator may have been frozen over (Credit: Alamy)

However, if we knew what happened in this prehistoric dark age, perhaps we would find some answers to these thorny scientific puzzles.

"This is an interval in Earth's history when a lot is happening," says Rebecca Flowers, an associate professor in the Department of Geological Sciences at the University of Colorado, Boulder. "…And all of these events clearly are related in some form, so trying to disentangle the relationships among these different processes in this key interval of Earth's history, I think is pretty fundamental," she says.

Theory 1: the snowball

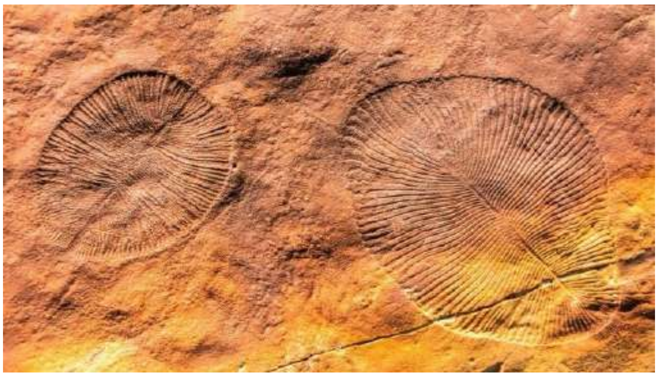
One idea about what caused the missing time hinges on what's happening on Earth's glaciers today. Take the second-largest ice body on the planet, the Greenland Ice Sheet, which covers around 80% of the country's surface – roughly 1.7 million sq km (656,000 sq miles).

Just like rivers, glaciers can also move – but very slowly. And as they do, they gradually scour away at the crust they're sitting on. If this continues for tens of thousands or even millions of years, eventually this erosion can abrade away significant quantities of rock. As a result, Greenland is riddled with the scars of its glacial history, such as deep valleys and dramatic fjords.

But while some parts of Greenland have been carved out by flowing ice, others have been protected by glaciers that were so hard and frigid, they didn't move at all – and kept the land underneath safely cocooned, free from any erosion. These areas have remained largely unchanged, and form the country's plateaus.

The former is what earth scientists call a "wet" glacier, while the latter is "cold", says C Brenhin Keller, an assistant professor in the department of Earth Sciences at Dartmouth College, New Hampshire.

Back when the Earth was a giant snowball, the theory goes, the same processes would have applied across the entire surface of the planet. So the only question is, how bitter was this era exactly – would the glaciers have been "wet" or "cold" – and could any amount of ice have eroded away a billion years of rock?



The ancient creature known as Dickinsonia might have been a fungi, an animal, or entirely new to science (Credit: Alamy).

Back in 2018, together with colleagues from a number of other universities, Keller attempted to answer this question. Based on a model developed by another group several years before, they assumed that snowball Earth would indeed have had a "wet" glacier on its surface, and it would have been surprisingly mobile.

That's because the global ice sheet would have collectively locked up so much water that the earth's sea level would have dropped dramatically. This in turn would have created a steeper gradient from the land to the sea, meaning that the glaciers on the earth's surface would be moving more rapidly – just as rivers speed up when they're running downhill.

Altogether, starting around 717 million years ago and ending around 580 million years ago, the team predicted that the frosty phase would have removed around 3-5 vertical km (1.9-3.1 miles) of rock – more than enough to account for The Great Unconformity.

"I think there's every reason to believe that this was fairly erosive," says Keller, though he points out that the amount of lost rock wouldn't have been the same everywhere "because ice is a very hit or miss driver of erosion." This might explain why there is more missing rock in some parts of the world than others.

However, this can't have been the full story, because it would still be another 40 million years before much new rock was laid down. "And I think what is going on there actually is essentially, you've made the crust hotter by just having chopped off the coldest part. That makes it more buoyant," says Keller. This pushed up the land and paved the way for yet more erosion – the higher it is, the more quickly it's eroded by ordinary weathering such as rain and wind.

Theory 2: the death of a supercontinent

Another possibility is that the culprit was the supercontinent Rodinia – a forgotten landmass that concentrated East Antarctica, India, Siberia, China, a large chunk of South America, North America and assorted bits of Africa in one place. It first assembled around a billion years ago, and broke up gradually, until 750 million years ago.

Fjords form when glaciers carve out U-shaped valleys which are later filled with seawater (Credit: Alamy)

"It basically amalgamated all of the crust on the world into a single giant continent," says Michael DeLucia, a PhD student in the department of Geology at the University of Illinois who authored a paper on the subject. He explains that most heat from the centre of the Earth is normally released via mountain ranges on the seafloor – oceanic ridges – which occur at the boundaries of tectonic plates. But when all the land was pushed together, there weren't as many of these, so Rodinia got quite hot.

"And of course, when things warm, they expand," says DeLucia. "So it was basically the expansion below the super-continent that we think promoted this uplift event that caused around six to eight km (3.7-5 miles) of vertical uplift."

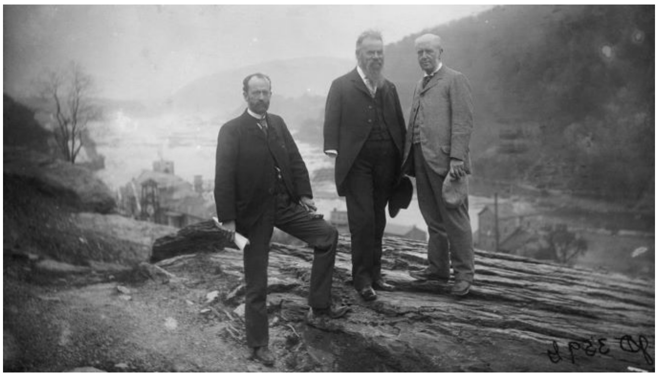
This not only accelerated the breakup of Rodinia, but may have erased the record of everything that happened in the preceding billion years – again, the land was higher and therefore more easily eroded.

According to this theory, Rodinia would have looked like a giant, hilly plateau for 200 million years – devoid of all life, which was still confined to the vast ocean that surrounded it. This was eventually eroded down to almost nothing. "And we see this erosion event across all current continents," says DeLucia.

But that wasn't quite the end of the story. The sheer amount of erosion involved would have changed the chemistry of the atmosphere and the oceans, leading to major climate change. It would have been the opposite of what's happening today – as rainwater scoured away the surface of the super-continent, this would have released calcium ions, which then washed into the ocean to form calcium carbonate (the main ingredient in chalk). Essentially, the erosion trapped carbon dioxide in the ocean, locking it out of the atmosphere and cooling down the Earth.

In this scenario, the planet would have turned into a snowball *after* the billion years went missing, rather than before.

"This then perhaps even scraped off more sediments," says Marshak, who was also involved in the research, "which enhanced and amplified The Great Unconformity." In the end, the older layers of rock beneath the fragmenting Rodinia would have been exposed, ready to join up directly with the new sedimentary rock that was laid down once the climate stabilised again.



Powell was known affectionately by the White River Utes people as "Kapurats", meaning "one arm off" (Credit: Alamy).

Whichever way it happened, the erosion of unfathomable quantities of rock and transfer of these sediments to the oceans is thought to explain the proliferation of life that occurred immediately afterwards, during the Cambrian. It's particularly striking that – at a time when there would be more dissolved minerals in the ocean than ever – many of the new lifeforms that emerged had skeletons and shells that require calcium.

However, Marshak is keen to stress that the debate is ongoing. "There are a couple of issues that are still contentious about it, and are still subjects of research," he says.

Theory 3: a confusion of gaps

This brings us to the most recent idea.

There are only two possible ways for a billion years to go missing – either no rock was laid down, or it was all removed (or both).

Though The Great Unconformity is most visible at the Grand Canyon, it's also accessible at a number of other locations, one of which is the Canadian Shield, a vast area of exposed ancient rock that encircles Hudson Bay in the country's north-east. And here recent research revealed a twist.

"It appears that the major erosion at the Grand Canyon occurred prior to the snowball glaciation," says Flowers, who was involved in the research, "whereas in the Canadian shield it occurred later, during or perhaps after, the snowball Earth glaciations."

This suggests that the epic interruption in the geological record was not a single, discrete phenomenon – but instead is actually at least two mini-gaps, which look like one big one because they occurred at around the same time.

Then earlier this year, there was another surprise. Just over 150 years after Powell's fateful expedition, Flowers and colleagues went back to the Grand Canyon to do their own investigations. What they found was striking: even the lost billion years at the Grand Canyon may not have disappeared at the same time, and may instead have vanished in several separate events over the course of several hundred million years.

Life before the Cambrian explosion consisted of a strange assortment of soft-bodied creatures, many of which would be unrecognisable today (Credit: Alamy)

"On these timescales, we're not really great at refining an age for missing time exactly," says Francis Macdonald, Professor of Geology at the University of California, Santa Barbara, who was also involved in the research. "And so the previous theory suggested that okay, it's all being formed once, with glaciation – but we're saying 'no it's been formed over hundreds of millions of years'… when you get better data, they [the unconformities] are not exactly correlative."

If the two sets of erased rock really are independent of each other, this suggests that they weren't caused by one extraordinary event like snowball earth after all. In this case, Flowers suggests that they might have been formed via tectonic processes which pushed vast quantities of the earth's crust upwards. There might have been no erosion either – it's possible that the higher altitude just made it difficult to deposit sediment, and therefore little rock was formed during this era in the first place.

An unsolved mystery

This is not quite the end, however. The debate continues – all the experts I spoke to emphasised the need for more data. And luckily this is likely to be forthcoming.

"I think there's [been] a renaissance of interest [in this geological enigma]," says Macdonald. A decade ago, there was relatively little research on The Great Unconformity and what caused it. But a surge of outlandish new theories – and the emergence of technologies capable of testing them – has transformed the field.

One major game-changer was a technique known as thermochronology, which involves extrapolating the history of rocks by measuring how their temperature has changed since they formed.

"So for example [with older methods], if somebody says that they dated a granite and it's 100 million years old, what they usually are referring to is the time at which it cooled from magma to become solid," says Marshak. With thermochronology, you aren't looking at when the rock formed, but roughly when it was pushed up to the Earth's surface – and this can tell you a lot about what was happening in our planet's deep past.

"This technique basically gave us a window to pull out the records of missing time," says Macdonald. Who knows what secrets they might reveal.

(Zaria Gorvett / BBC FUTURE, 1st September 2021, https://www.bbc.com/future/article/20210901-the-strange-race-to-track-down-a-missing-billion-years)

Geosynthetics solve the unique needs of wind energy projects

How to select geosynthetics for wind farms? As energy demands continue to rise throughout the world, renewable energy projects such as wind farms are taking off both locally and globally.

Turbines of the Altamont Pass Wind Farm, Altamont Pass, Calif. Photograph by Eric Molina, Creative Commons License: https://creativecommons.org/licenses/by/2.0/deed.en

The 2021 United Nations' Intergovernmental Report on Climate Change (IPCC) states that "global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in carbon dioxide (CO_2) and other greenhouse gas emissions occur in the coming decades."

This and other findings have put more pressure on global leaders to transition to renewables, limiting CO_2 emissions from fossil fuel energy and supporting renewable energy solutions such as solar and wind power.

While the groundswell of support for these projects represents a step forward from an environmental perspective, the actual construction of wind energy farms can be a challenge. This is due to a wind farm's unique requirements, such as the incredible weight of the turbines and the ground strength needed to ensure long-term stability on-site.

So how can renewable energy firms manage the construction phase with the least amount of environmental impact and the best long-term outcomes?

Wind farms have unique requirements

Due to their size and the conditions required to ensure the project's success, wind energy projects are often located in remote greenfield areas. Many of these locations feature poor soil conditions, weak subgrades and other environmental conditions that can make construction a challenge.

Some common design considerations include:

- Subgrade stabilization and improvement
- Strengthening access and haul roads
- Building working platforms or pads
- Creating foundations that can resist rotational movement
- Slope stabilization in the surrounding area

Access roads

Wind farms require soil that can support extremely heavy loads. This is not just a factor for the installed turbine, but also, crucially, the access roads on-site. With segments of each turbine weighing up to 55 tons (50 tonnes), and the total assembly often nearing 330 tons (300 tonnes), extreme ground reinforcement is needed to ensure each component can be transported successfully to its destination.

Transporting the wind turbines is a mammoth task: for each turbine, approximately 50 concrete trucks, steel reinforcement, the tower, the blades and the turbine must access the site over the course of a few months.

This puts enormous pressure on the access roads, which are often temporary constructions that must endure short-term, heavy loading and then perform well as a light-duty maintenance road for the remainder of their design life—sometimes up to 50 years.

Using geosynthetics to strengthen and reinforce soft subgrades presents a good solution, with a combination of geotextiles and geogrids with heavy-duty loading often providing a positive outcome. Selecting geosynthetics that offer base reinforcement and subgrade stabilization, such as Secugrid and Combigrid from Global Synthetics means that the project will have high strength at low strain—an absolute necessity for this type of application.

Cost-effective, easy to install and with a long design life, geosynthetics can handle the heavy traffic loading (typically axle loading of around 90 kN) without the need to pave miles of temporary road.

These geogrids possess uniform strength in their welded bars, creating a rigid, stable, two-dimensional grid that is as strong in its longitudinal direction as in its transverse direction.

Secugrid has been successful in a range of wind farm applications including a Tasmanian renewables project involving 31 turbines and 12.4 miles (20 km) of access roads. The successful construction of this 112-MW project resulted in Tasmania achieving its goal of a 30% increase to its renew-able energy capacity.

Pads and platforms

Like the access roads, wind turbine pads must be strong enough to support the long-term placement and continual rotation of the giant turbines. Base foundations need to be built on strong and stable soil, otherwise, the foundations can sink and knock the turbine out of alignment with potentially disastrous consequences.

In one case, during a wind farm project in Eaglesham Moor in Scotland, the peat subgrade was collapsing while the base foundations for the pads were being dug.

This region's soils are extremely challenging for this type of construction, with depths of up to 23 feet (7 m) covered with 10 feet (3 m) of glacial till. Roughly two-thirds of the site is located on these types of soils, which are unable to support conventional concrete gravity foundations for the pads.

Geotechnical issues of turbine pads such as this can be managed through a combination of increasing concrete base sizes, extensive pile work geosynthetic support.

Geosynthetics may not always be the sole solution, however, they are frequently used in conjunction with other methods to achieve a good result for pads and platforms

Which geosynthetics are recommended for wind farms?

Engineered geogrids can often provide a sustainable solution for wind farm construction on soft or challenging soils. Choosing a geogrid like Secugrid can reduce the required thickness of the granular layer for access roads and hardstands, providing considerable cost savings and reduced construction time.

This article originally appeared on the Global Geosynthetics Blog, https://globalsynthetics.com.au/blog.

(IFAI, September 7, 2021, https://geosyntheticsmagazine.com/2021/09/07/geosynthetics-solve-the-unique-needs-of-wind-energy-projects)

NASA's Perseverance Mars Rover

I've captured my first Mars sample and I'm ready to core a second sample from this same rock. This time, I will run through the entire process of coring and sealing the tube without pausing. #SamplingMars continues. My team to share the latest Friday: http://go.nasa.gov/3jSTjjE

(Sep 8, 2021, https://twitter.com/NASAPersevere/status/1435367437071896576

NASA to Host Briefing on Successful Sample Collection of Martian Rock

https://www.youtube.com/watch?v=IMyuOBexwE0&t=597s

Panelists will discuss the Perseverance rover's successful collection of the sample and latest science analysis.

NASA will hold a virtual media briefing Friday, Sept. 10, at noon EDT to provide an update on the agency's Perseverance Mars rover, which recently completed its first successful rock sampling.

The event will be livestreamed on NASA Television, the NASA app, the agency's website, and multiple agency social media platforms.

The briefing will also discuss what the rover's instruments have learned about the rock from which the sample was taken, and implications for a future sample retrieval mission. Through the Mars Sample Return campaign, NASA and ESA (European Space Agency) are planning a series of future missions to return the rover's sample tubes to Earth for closer study.

Briefing participants include:

- Lori Glaze, director of NASA's Planetary Science Division at the agency's headquarters in Washington.
- Jessica Samuels, Perseverance surface mission manager, NASA's Jet Propulsion Laboratory in Southern California.
- Matt Robinson, Perseverance strategic sampling operations team chief, JPL.
- Katie Stack Morgan, Perseverance deputy project scientist, JPL.
- Yulia Goreva, Perseverance return sample investigation scientist, JPL.
- Meenakshi Wadhwa, Mars sample return principal scientist, JPL and Arizona State University.

Members of the media and the public may ask questions on social media during the briefing using #AskNASA.

This composite of two images shows the hole drilled by NASA's Perseverance rover during its second sample-collection attempt. The images, which were obtained by one of the rover's navigation cameras on Sept. 1, 2021 (the 190th sol, or Martian day, of the mission), were taken in the "Crater Floor Fractured Rough" geologic unit in Mars' Jezero Crater. The team nicknamed the rock "Rochette" for reference and the spot on the rock where the sample was cored "Montdenier."

A key objective for Perseverance's mission on Mars is astrobiology, including the search for signs of ancient microbial life. The rover will characterize the planet's geology and past climate, pave the way for human exploration of the Red Planet, and be the first mission to collect and cache Martian rock and regolith (broken rock and dust).

Subsequent NASA missions, in cooperation with ESA (European Space Agency), would send spacecraft to Mars to collect these sealed samples from the surface and return them to Earth for in-depth analysis.

The Mars 2020 Perseverance mission is part of NASA's Moon to Mars exploration approach, which includes Artemis missions to the Moon that will help prepare for human exploration of the Red Planet.

JPL, which is managed for NASA by Caltech in Pasadena, California, built and manages operations of the Perseverance rover.

Perseverance landed in Jezero Crater Feb. 18, and the rover team kicked off the science phase of its mission June 1. The rover made a first attempt to collect a sample in early August, but the rock crumbled during the process of drilling and coring.

For its second attempt, the rover drove to a different location, where the team selected a rock that the the Perseverance team nicknamed "Rochette." The sample collection process began Sept. 1, and Rochette held up better.

Over the past week, scientists have been using Perseverance's instruments to analyze the rock from which the sample was taken. The sample itself would be examined back on Earth in ways that are not possible on the Martian surface, including with instruments far too large to take to Mars.

Subsequent NASA missions, in cooperation with ESA would send spacecraft to Mars to collect Perseverance's sealed samples from the surface and bring them to Earth for in-depth analysis.

A key objective for Perseverance's mission on Mars is astrobiology, including the search for signs of ancient microbial life. The rover will characterize the planet's geology and past climate, pave the way for human exploration of the Red Planet, and collect and cache the first samples of Martian rock and regolith.

The Mars 2020 Perseverance mission is part of NASA's Moon to Mars exploration approach, which includes Artemis missions to the Moon that will help prepare for human exploration of the Red Planet.

JPL leads the Perseverance mission and is managed for NASA by Caltech in Pasadena, California.

To learn more about Perseverance, visit:

nasa.gov/perseverance and mars.nasa.gov/mars2020/

(https://mars.nasa.gov/news/9030/nasa-to-host-briefing-on-successful-sample-collection-of-martian-rock)

NASA's Perseverance Mars Rover

My first two rock samples are likely volcanic with hints of salts that may hold bubbles of ancient water. They're pieces of a bigger puzzle, to learn: - how this area formed - its history of water - if past life ever existed here More on #SamplingMars: http://go.nasa.gov/3jZ0syN

(Sep 10, 2021, https://twitter.com/NASAPersevere/status/1436366199424569346)

NASA's Perseverance Mars Rover

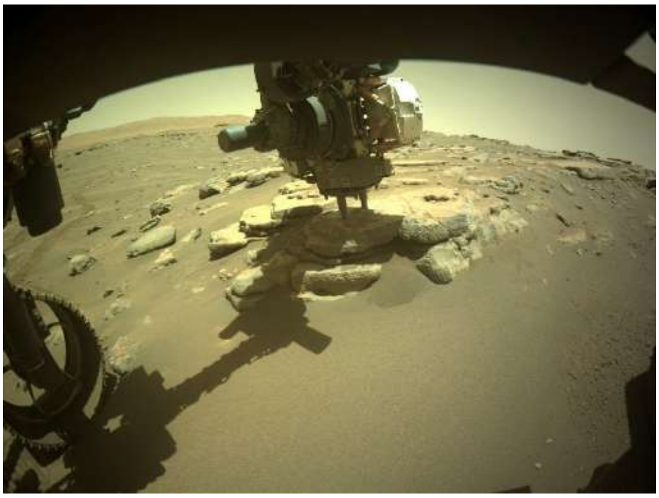
I core rocks, do science and occasionally I take selfies. I took this one at "Citadelle" after collecting two rock cores from the rock "Rochette," shown here on the bottom left.

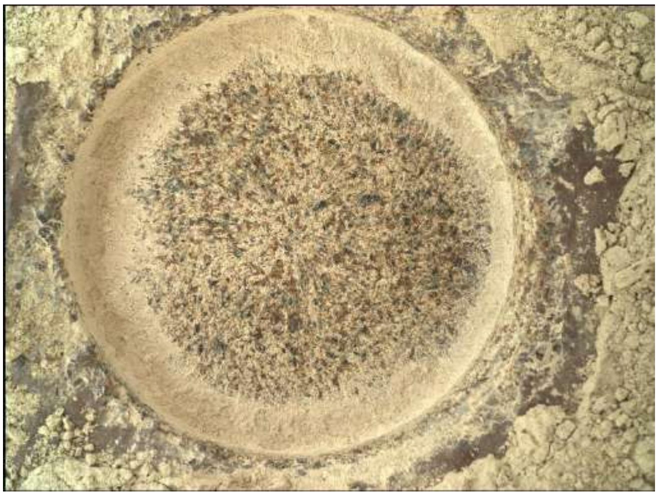
See more pics: http://go.nasa.gov/3zkNccg Learn how I take selfies: http://go.nasa.gov/35PjDTJ

(Sep 20, 2021, https://twitter.com/NASAPersevere/status/1440012002504544257)

NASA's Perseverance Mars Rover

Where a human geologist would use a rock hammer to crack a rock open and look inside, I've got my abrasion tool to make little windows into Mars history for me. Here's what my latest rock target looks like inside. More images: http://go.nasa.gov/perseverance-r





(Sep 21, 2021)

The 373 B.C. Helike (Gulf of Corinth, Greece) Earthquake and Tsunami, Revisited

Stathis C. Stiros [1]

Abstract

Ancient authors report the destruction and drowning in 373 B.C. in the Gulf of Corinth (Greece) of Helike (Helice and Eliki), an important, nearly coastal town, and of Boura (Bura, Buris, Bouris, and Voura), another town in the hinterland, as a punishment by the ancient God Poseidon because of a serious crime committed in his shrine. This narrative has been regarded as a description of a true event, though with some exaggerations, and the 373 B.C. event is included in earthquake and tsunami catalogs. In the first part of this article, it is shown that (1) local natural hazards exclude the possibility (risk) of total loss of the ancient "polis" (town state) of ancient Helike because of its vulnerability due to its geography. (2) Systematic geoarchaeological studies confirm this prediction because they reveal essentially undisturbed archaeological layers predating and postdating 373 B.C., with no signs of a tsunami. (3) Archaeological excavations have recently brought to light, among other findings, remains of the harbor of Boura and of the shrine of Poseidon at Helike, as well as coins issued by Helike several decades after its alleged loss. This evidence permits a reconsideration of ancient texts related to the loss of Helike in a supervised learning-type approach. It was found that genuine ancient Greek texts do not mention any catastrophe of Helike, but rather that the legend of its total loss appeared several centuries later in Roman times, in local legends, rumors, and forged or manipulated ancient texts (e.g., by pseudo-Aristotle). The ancient legend became important because it explained the collapse of the town state of Helike and it fit ancient religious ideas in a tectonically active region because of the rapid burial ("disappearance") of ancient Greek remains under sediments in a young delta and because of the prominent location of Helike in the seafaring route between Rome and the eastern Mediterranean.

For earthquakes before our era, historical and archaeological data have attracted interpretations… attributing to earthquakes… the demise of flourishing city-states.

…The reason for the revival of catastrophe hypotheses is perhaps that they are easy to explain. They are too simple, too obvious and too coincidental and chiefly because they have become fashionable in recent years. (Ambraseys, 2006)

Introduction

An earthquake reported to have hit the Gulf of Corinth in Greece, in 373 B.C. (Figs. 1 and 2), combining both a tsunami and ground deformation, is among the most famous though ambiguous seismic events in antiquity. Information about this event is conveyed by more than a dozen ancient authors, most writing several centuries later. Their basic scenario is that the towns of Helike (Helice and Eliki) and nearby Boura (Bura, Buris, Bouris, and Voura) committed a horrible crime in an important sanctuary of Poseidon. For this reason, Poseidon, god of seas and earthquakes, punished the two sinful towns with an earthquake and a tsunami, which moved the two towns with all their inhabitants under the sea, with their remains being visible under the water for centuries afterward (see Table 1 and Table S1, available in the supplemental material to this article, which summarizes the ancient texts; for a complete list of ancient sources, see Rizakis, 1995; Morgan and Hall, 2004; see also the website of Topostext Foundation in the Data and Resources section).

Although scenarios of the loss of towns (Hansen and Nielsen, 2004, index 20) and of punishment by gods are not unusual in the ancient Greek and Roman cultures and literature ("providentialism"; Stiros, 2020a), and although the reports for Helike and Boura are controversial (see Table 1), the 373 B.C. event has been adopted by scholars, for example Anderson (1954), Baladie (1980) and has been included in earthquake and tsunami seismic catalogs (Guidoboni et al., 1994; Ambraseys and White, 1997; Papazachos and Papazachou, 1997; Papadopoulos, 2003; Ambraseys, 2009). This is due to four factors: (1) the 373 B.C. catastrophe seemed to be reported by prestigious ancient authors such as Aristotle, Strabo, Pausanias, and Seneca; (2) Helike was the leading town of the Achaia League, a confederation of town states in northwest Peloponnese, but it disappeared from the political scene after approximately 300 B.C.; (3) the wider area is crossed by the Aigion fault (or Eliki fault; Fig. 3), which was reactivated in 1861, producing subsidence of a narrow strip of coastal land (see Mouyaris et al., 1992; Ambraseys and Jackson, 1997) and hence providing a parallel for the ancient disaster, although at a very small scale; (4) the legacy of S. Marinatos, an imaginative archaeologist, highly influential after the discovery in Santorini in the 1970's of remains of the prehistorical town of Akrotiri that was buried by pumice during the famous Minoan eruption. Marinatos had suggested that the ancient texts describe a true event, and he promised that the discovery of a drowned Helike would represent an archaeological discovery of unsurpassed significance and wealth (Marinatos, 1960). This scenario was appealing because of the advent, at that time, of underwater archaeology.

Figure 1. Gulf of Corinth in the framework of the marine routes of the eastern Roman Empire. Helike was at a prominent position of this route, near the western entrance or exit of the Gulf of Corinth.

Figure 2. Gulf of Corinth, location map.

The approximate location of ancient Helike is known to be near the modern village of Helike on the delta of the modern Kerynitis and Selinous Rivers, a few kilometers west of the modern and ancient town of Aigion (Figs. 2 and 3). In this area, no signs of classical remains had been found until recently (Anderson, 1954), giving some weight to the hypothesis of a lost town. On the other hand, Boura, the second town described as punished by Poseidon, has been identified with extensive ancient remains near Ano Diakopto (for location, see Fig. 3), in a mountainous area (see Rizakis, 1995; Kolia, 2007).

TABLE 1
Summary of Historical Information for Helike and Boura

Years since 373 B.C.	Author	Reference to	Reference to Comet	Earthquake Date (B.C.)	Reference to Helike	Reference to Boura	Additional Information
0	Aristotle 1, 2 (384–322 B.C.)		Yes	373	No	No	Eq&ts in Achaia, natural effects
0	Xenophon (430–354 B.C.)				No	No	
250	Polybius (200–118 B.C.)			>371	Swallowed by sea	Main town in about 280	
	Diodorus 1 (90–30 B.C.)			373	Destroyed by eq&ts	Destroyed by eq&ts	Natural events or crime "A"
	Diodorus 2		Yes	372			Comet NOT correlating with HB
	Diodorus 3					Main town in 303 B.C.	
350?	Pseudo-Aristotle (100 B.C.–??)				Tsunami	Tsunami	Later forged text
400	Strabo 1,2,3,4 (63 B.C.–A.D. 23)			373	Submerged in sea	Lost in seismic chasm	Crime "B"
	Strabo 5	Rumors for third-century B.C. Eratosthenes			Visible drowned remains		Unreliable, later rumors
	Strabo 6	Rumors for fourth-century B.C. Heracleides			2 km from coast, drowned		Helice land usurped (?)
400	Philo of Alexandria (20 B.C.–A.D. 50)	Verses-legend			On high land, drowned	Drowned	Aigeira also drowned
400	Ovid (43 B.C.–A.D. 18)	Verses			Drowned, walls visible	Drowned, walls visible	
400	Seneca 1,2,3,4 (4 B.C.–A.D. 65)	Callisthenes (fourth-century B.C.), forged or rumor			Attacked-drowned by sea	Attacked or drowned by sea	Aigion not affected-eq portends
	Seneca 5	Callisthenes (fourth-century B.C.) forged or rumor Aristotle mentioned	Yes		Drowned	Drowned	First connection between Aristotle's comet-eq&ts and HB
	Seneca 6	Ephorus fourth-century B.C.	yes		—	—	Manipulated refence to Ephorus
450	Pliny the Elder 1 (A.D. 24–79)				Drowned traces visible	Drowned traces visible	
	Pliny the Elder 2				Refounded	Refounded	Or reconstructed by survivors
	Bianor Bithynius (first-century A.D.)	Verses			Drowned	Drowned	
500	Pausanias 1, 2, 3 (A.D. 110–180)	Local legend-area visited		373	Earthquake destruction, drowning		Crime "C"; ruins offshore not really visible
	Pausanias 4	Local legend		373		Destroyed, refounded	Or reconstructed by survivals
500	Polyaenus (second century)				Eq&ts		Crime "D"
600	Claudius Ptolemeus A.D. 100–170				Existing continental town	Existing continental town	Coordinates provided
600	Aelian (A.D. 175–235)				Eq&ts subsidence		Portend, animals,
600	Philostratus (A.D. 170–250)				Drowned by sea	Lost in chasm	Both in Thessaly, not Achaia
750	Ammianus M. (A.D. 330–395)				Lost in a chasm	Lost in a chasm	
800	Orosius (375–420)				Lost in a chasm	Lost in a chasm	All Achaia destroyed

Crime: god punishment for crimes: "A," impiety to gods; "B," disobedience to Achaean council decision; "C," killing suppliants; "D," killing suppliant gir; eq, earthquake; Eq&ts, earthquake and tsunami; HB, Helike and Boura.

Figure 3. Oblique Google Map photo showing the area of ancient Helike between the Kerynitis and Selinous Rivers, view to the south. The Helike fault marks the southern margin of the Aigion–Helike coastal plain, a composite delta. Dots with numbers indicate approximate locations of sites of archaeological excavations mentioned in the Archaeological Excavations: Discovery of Remains of Ancient Helike and Boura section.

Inspired by Marinatos (1960), marine investigations for the search of ancient Helike started in the last decades of the twentieth century, but they proved unsuccessful (Schwartz and Tziavos, 1979). This was because the continental shelf of the critical area, a Quaternary delta in a tectonically active area marked by a 900 m deep gulf, is dominated by slumps. For this reason, geoarchaeogeological studies were shifted inland, searching for the ancient town beneath recent sediments through geoarchaeological studies (Alvarez-Zarikian et al., 2008). In addition, archaeological investigations and excavations in the wider region were carried out mostly by the Greek Archaeological Survey.

This article tries to shed light on this famous earthquake using a new approach: the overall study is not a priori constrained by the theory that the loss of Helike in 373 B.C. was a true event, as was the case of most previous investigations. This study first focuses (1) on the scale of natural hazards in the critical area; (2) on the vulnerability of a "polis," an ancient Greek town state (Morgan and Hall, 2004) as a result of its geography; and (3) on the prediction of the risk of the loss of Helike. This prediction is then juxtaposed with results of the available geological, geoarchaeological, and archaeological studies in the wider region. The output of this combined investigation is then used to evaluate ancient texts referring to the loss of Helike in a type of "supervised learning." These ancient texts were analyzed using not the traditional approach, that is, regarding sources of information as complementing each other, but as a function of the passage of time since 373 B.C. In addition, these ancient texts were critically evaluated using the most recent archaeological and geoarchaeological evidence and are summarized in Table 1 and Table S1, in which references are given in a coded form, for example "Aristotle 1" or "Polybius." The overall output is that no physical loss of the classical town state of Helike occurred and that this alleged loss represented a legend from Roman times, several centuries after 373 B.C. (for archaeological and historical terminology, see Table S2).

Apart from its importance to historical seismology, shedding light on this event is important for various other disciplines focusing on aspects of the ancient world. This is because, lacking other evidence, the archaeological stratigraphy in seismically active regions is constrained by destruction layers or abandonment periods, which are frequently a priori assigned to earthquakes (Stiros, 2020b) and are then used to date older or younger layers. The 373 B.C. earthquake is among the earthquakes that have been extensively used as a dating benchmark in the archaeological stratigraphy in a broad region (e.g., a review of archaeological work by Tomlinson, 1996). In addition, Helike has been used to date ancient texts and events in most reaches of the ancient world. For example, if an ancient book on navigation of coasts mentions Helike, it is dated before 373 B.C., and ancient towns and events mentioned are also dated before 373 B.C. If Helike is not mentioned, the book and events reported (wars, etc.) are dated after 373 B.C. (Rizakis, 1995). This shows the importance of historical seismology, for example, for research in archaeology and ancient history.

Previous Scenarios for the Loss of Helike

Currently, there are three groups of scenarios to explain ancient texts referring to Helike.

First, supporting the views of Marinatos (1960), Ferentinos et al. (2015) argued that an earthquake not accompanied by a tsunami produced a huge translational landslide that swept the upper levels of soil to the sea bottom, but preserved deeper, older occupation horizons represented by excavated ancient remains.

Second, there are the views of scientists collaborating with the "Helike Project." After sonar surveys discarded the possibility of finding ancient remains offshore, the study of this group was directed to the young sediments in the delta between the modern Selinous and Kerynitis Rivers. Based on sedimentological evidence, various scenarios have been proposed by this group following the progress of their study. A first hypothesis was that Helike was buried in a coastal lagoon (i.e., a trench) that opened inside the delta because of the 373 B.C. earthquake (Alvarez-Zarikian et al., 2008). Subsequently, based on high-quality analysis of sedimentological data, the possibility of a major tsunami and of significant deformation of the delta sediments was discarded. Furthermore, based on identification of buried archaeological layers of the classical period, it was proposed that Helike survived the famous earthquake, the impacts of which were exaggerated by ancient authors (Engel et al., 2016). In a more recent article, the absence of ground deformation during the 373 B.C. earthquake and the survival of Helike were again endorsed, but to explain the ancient texts, it was proposed that the ancient town was swept by water and mudflow after the breaching of a 30–60 m high dam and lake which were produced by seismic landslide debris in a river valley, a few hours after the earthquake (Koukouvelas et al., 2020).

Third, there are the views of scientists and archaeologists critical of the idea of a total loss of Helike that are based on different evidence essentially ignored in the past. (1) M. Petropoulos, based on the first excavations of the Greek Archaeological Service, proposed a continuity of Helike after 373 B.C. and argued that its urban center was close to the southern limit of the coastal plain (between sites 3 and 5 in Fig. 3; for references, see Morgan and Hall, 2004). Petropoulos (1983) had also questioned the scale of the alleged disaster because it was ignored by fourth-century authors such as Aristotle and Xenophon, who were fully aware of the history of northwest Peloponnese around 373 B.C. (2) Stiros (1996) argued that the scale of the alleged destruction is too large to be explained by any combination of natural effects, whereas some details of the ancient texts referring to the loss of Helike, ignored by modern authors, indicate later legends (Faraklas, 1998). For example, after the postulated earthquake, tsunami, and subsidence of the land by tens of meters, it was unlikely that a statue of Poseidon would have remained standing erect at the sea bottom for centuries; if the area between the Selinous and Kerynitis Rivers had been swallowed by the sea, it is unlikely that Aigion suffered no damage only a few kilometers away (Figs. 2 and 3; Seneca 2). (3) Faraklas (2001), in a detailed study of the history and geography of ancient Achaia, argued that Helike was damaged in 373 B.C. and probably lost its harbor, and as a consequence, it disappeared as an organized town but survived in smaller villages in upland areas; a scenario broadly similar to that of Mackil (2004).

Seismic Hazard, Vulnerability, and Risk of Helike and Boura

Physiographic and seismotectonic background and natural hazards

The Gulf of Corinth, a tectonic graben about 900 m deep, represents a major geomorphological discontinuity in Greece that offered a connection between the Aegean and the Ionian and Adriatic Seas. For this reason, the Gulf of Corinth was a main part of the seaway from the Aegean Sea and Asia Minor to Italy (Fig. 1) since the eighth century, when Greek towns, including Helike, established colonies in southern Italy. However, the connection between the Aegean Sea and the Adriatic Sea is disrupted at the eastern edge of the Gulf of Corinth by the 6 km wide Isthmus of Corinth, a tectonic horst uplifted since Pliocene (Fig. 2), famous for the nineteenth century Corinth Canal. In antiquity, ships with their cargos, when crossing the Gulf of Corinth, were pulled on land along a 6 km long slipway in the form of a double ramp ("Diolkos") across the Isthmus. To facilitate the transportation of goods across the Isthmus, effort to excavate a canal was made in the Roman times. Ancient Corinth, with harbors in the Gulf of Corinth (Lechaio) and the Aegean Sea (Kenchreai), had a strategic position in the ancient maritime route between Italy and the Aegean and eastern Mediterranean (Figs. 1 and 2).

Coastal uplift is not limited to the Isthmus; the whole south coast of the Gulf of Corinth is marked by flights of marine terraces several hundred meters high, especially preserved in the area of Corinth (Kelletat et al., 1976; Keraudren and Sorel, 1987; de Martini et al., 2004). The uplift culminates in the center of the gulf. For this reason, the sea-level mark in the Roman harbor of Aigeira is currently at a height of 4 m (Stiros, 1998; for location, see Fig. 2). Corals and other marine species in nearby rock provide evidence of an uplift of 9 m in the past 7000 yr. Similar data provide evidence of an uplift of 11 m in the past 5000 yr farther west, close to the site identified as the harbor of Boura (Stewart and Vita-Finzi, 1996; Pirazzoli et al., 2004).

The wider Gulf of Corinth area is seismically very active, and in the last centuries, it experienced several significant earthquakes each century (Ambraseys and Jackson, 1997; Papazachos and Papazachou, 1997).

The Gulf of Corinth area is crossed by numerous active faults; among them is a fault known as Aigion or Eliki fault, which limits the Selinous–Kerynitis delta to the south (Fig. 3; Mouyaris et al., 1992; Stewart and Vita-Finzi, 1996; de Martini et al., 2004). Faults in the Gulf of Corinth, however, are less than 20–25 km long, and this length limits earthquakes on this and on nearby faults to M 7.0 or less (Roberts and Jackson, 1992). For this reason, Ambraseys and White (1997) concluded that ancient texts describing the loss of Helike originated from a moderate seismic event, the impacts of which were exaggerated because of possible religious implications.

Natural hazards in the wider Helike and Boura area

The 1995 M 6.2 Aigion earthquake produced horizontal acceleration exceeding 0.5g, with catastrophic effects on traditional houses (Athanasopoulos et al., 1999), which share common dynamic characteristics with ancient houses. This earthquake reveals that earthquakes represented a major threat to ancient towns as well. Evidence from an earthquake that hit the area in 1861 producing seismic faulting and subsidence of a strip of land indicates the possibility of seismic faulting of the order of 1 m, occasionally associated with drowning of coastal strips of land or, alternatively, of coastal uplift (Stiros, 1998; Pirazzoli et al., 2004). Local ground instability effects, such as liquefaction and landslides, were also possible. Landslides may produce damming of rivers inside gorges (Koukouvelas et al., 2020) and loss of coastal strips of land. In 1963, an aseismic slump near Aigion led to the loss of a small part of cultivated land and to a tsunami hitting the two sides of the Gulf and killing people (Galanopoulos et al., 1964). However, dramatic geomorphological changes, such as drowning of a major part of the delta, for example, of the area between the Selinous and Kerynitis Rivers (i.e., of the location of ancient Helike) with a maximum elevation above 40 m (Fig. 3), can be excluded.

Geography, Vulnerability, and Seismic Risk of Helice and Boura

Seismic vulnerability of a polis (town state)

Helike was a "polis," a town state with long history (Morgan and Hall, 2004), and hence it was expected to consist of a fortified main administration, military, and religious center ("acropolis") and of satellite inhabitation centers around it. For example, ancient Athens, another polis, consisted of an urban center around an acropolis, known as the Acropolis, along with 100 communities ("demoi"), some representing fortified small towns. Rural Sparta, on the contrary, consisted of numerous small villages and did not include a main urban fortified center.

Furthermore, ancient Greek towns with a long history were built on safe and favorable environments, avoiding unstable ground and unhealthy areas; only isolated shrine complexes could have been located in areas not satisfying the aforementioned conditions. Ancient towns with a long history were resilient, and failure of the water supply system was the only environmental reason for rapid abandonment of organized towns in the region. If this was, indeed, the reason for rapid abandonment, the remains of the civil infrastructure would still be visible (e.g., Di Vita, 1996).

Helike, which had a long history (it was mentioned by Homer, Iliad b, 575), could not have been an exception. Because of the variability of the landscape (Fig. 3), the inhabitation centers of the town state of Helike should have been distributed among different physiographic environments: a fertile plain, exceeding an elevation of 40 m at its southern margins, a hill >200 m high hosting its acropolis, and small isolated plains in the hinterland. The distribution of the polis of Helike to different physiographic settings limited its vulnerability to strong earthquakes and made virtually impossible the risk of the total loss of its structures (houses, fortifications, etc.) due to an earthquake and its accompanying effects.

Boura also represented a town state in a mountainous area (Figs. 2 and 3), most probably including several settlements on intramountain small plains and a harbor. The same conclusion about the seismic risk of Helike also applies to the polis (town state) of Boura.

Archaeogeological and Archaeological Evidence

Numismatic evidence: Helike and Boura existed for decades after 373 B.C.

The only physical evidence presented until recently for the existence of Helike was two coins issued by the town state of Helike (Marinatos, 1960). These coins have been a priori assumed to predate the destruction of 373 B.C. Recent excavations have brought to light additional coins of Helike, which have been examined by Weir (2017). His conclusion is that the dimensions and iconography of all of these coins indicate that they had been minted several decades after 373 B.C. This means that the polis-state of Helice existed at least for about 50 yr after its alleged loss. Numismatic evidence from the harbor of Boura also indicates an essential continuity of inhabitation between approximately 600 and 230 B.C. (Kolia, 2007, 2018).

Geoarchaeological evidence: Large-scale ground stability and no 373 B.C. tsunami

In the past 30 yr, an extensive program of boreholes, mostly shallow, has been drilled in the Helike area, with the main focus in the part of the delta between the modern Selinous and Kerynitis Rivers (Fig. 2). These studies have identified archeological layers predating and postdating 373 B.C. and indicate an overall ground stability, though with local stratigraphic perturbations (Soter and Katsonopoulou, 2011; Engel et al., 2016), which are definitely expected in an active young delta in a tectonically active area.

In addition, no signs of sediments that may support the possibility of a major tsunami in 373 B.C. have been found in drillholes. This result is consistent with the results of Kortekaas et al. (2011) at Alyki near Aigion (Fig. 3), a site that could have served as a trap for tsunami deposits.

Archaeological excavations: Discovery of remains of ancient Helike and Boura

Until recent decades, the absence of archaic and classical remains (i.e., before 320 B.C.) was striking in Achaia (Anderson, 1954). This was to a major degree due to the fact that ancient remains found during the excavation of the railroad in the 1880s and major roads in the 1960s were destroyed without any report, either because ancient remains were underestimated or to avoid problems in the works. This situation changed after a large number of archaeological excavations were made mostly by the Greek Archeological Service (see, e.g., Kolia, 2015). The output of these studies is summarized by Kolia (2011) and in Kolia (2015), who presented an illustrated summary of excavations.

1. On the steep hills marking the south limit of the delta, there have been identified remains of the acropolis (site 4 in Fig. 3) and of a cemetery (site 2 in Fig. 3) of Homeric (Mycenean) Helike (for archaeological terminology, see Table S2).

2. On the acropolis hill (site 4), the remains of a Hellenistic temple (roughly of the times of Alexander the Great), excavated by P. Petropoulos, indicate continuity of inhabitation in the area after 373 B.C.

3. Along the south margin of the plain there are remains of a settlement of the Homeric period (site 3) and of an earlier (Early Helladic) settlement (site 5).

4. The remains of a geometric sanctuary, built on the remains of an older shrine, have been found at site 1. Various artifacts indicate that it represents the sanctuary of Poseidon (Fig. 4a,b; Gadolou, 2011), which was the central point of the ancient legend. This sanctuary was much older and very different from the monumental ancient Greek temples. Next to it, there were found remains of public buildings and of a dumping site for material from the destruction of a nearby archaic temple, the foundations of which have not yet been excavated. The destruction of this temple is dated to the fourth-century B.C.

5. Site 6 is a representative site in which remains of an Early Helladic settlement were found beneath building remains of the Roman period. In several other nearby sites, ancient Greek ruins were found buried by layers of sediment beneath layers containing building remains or artifacts of the Roman period.

6. At the east edge of the complex delta, extensive excavations have brought to light the remains of an ancient coastal settlement (Fig. 4c), which can be identified with the harbor of ancient Boura (Fig. 3). The available data, however, do not provide any information about the harbor installations (Giaime et al., 2019). A rather continuous period of occupation, from approximately 500–230 B.C., is inferred from numerous coins, permitting an accurate dating of occupation layers (Kolia, 2018). Two destruction layers in this site (Fig. 4d) at about 290 and at 230 B.C., marking the abandonment of the site, were possibly associated with earthquakes. Evidence from this site, which is in an area of rapid Holocene uplift (Pirazzoli et al., 2004), excludes the possibility of significant marine regression in 373 B.C.

Re-examination of Historical Sources

For five days before Helice disappeared all the mice and martens and snakes and centipedes and beetles and every other creature of that kind in the town left in a body by the road that leads to [the mountains]. (Aelian, About the nature of animals, 11, 19).

Figure 4. Recently found ancient building remains of (a) Helike and (c) Boura. Foundations stability and the overall environment of these remains exclude the possibility of major geomorphological changes induced by the 373 B.C. earthquake and of physical loss of these two towns. (a) Foundations of the shrine of Poseidon of Helike (site 1 in Fig. 3) and (b) its reconstruction. This apsidal shrine, partly excavated, is typical of the geometric period (900–700 B.C.) and very different from the later classical temples. (c) Excavations of the Boura harbor, showing foundations of several houses, each with several rooms; view after the site was cleaned. The railroad near the coast destroyed part of the site in the 1880s, but no ancient remains were reported. This site spans the period of approximately 500–230 B.C. and was marked by two major destruction layers. (d) Destruction layer (fallen rooftiles) in a room of this complex, possibly related to an earthquake at about 290 B.C. (panels a,c,d excavations photos, courtesy of E. Kolia, panel (b) modified after Kolia, 2011).

The previous evidence excludes the possibility of the total loss of Helike and Boura because of major geomorphological changes during an earthquake and indicates that both towns existed as organized centers for decades after 373 B.C. This calls for a new reading of historical sources, such as the one in the overhead of this section, which seem to report highly exaggerated or fake events. This study differs from previous approaches in three points.

First, the loss of Helike is not regarded as an a priori true event, but as an at least exaggerated event.

Second, ancient sources of different periods are not a priori regarded as sources of information complementing each other, but rather their accuracy is regarded as a function of the time since 373 B.C.

Third, genuine ancient texts are separated from later, fabricated texts, for example, that written by pseudo-Aristotle. In addition, information provided by authors of the Roman period is critically analyzed, making a distinction between personal observations, explicit citations of authors of older periods, and indirect information and rumors. The latter are inferred to correspond to an expression that is literary translated as "it is said that.," but rather meaning "rumors are spreading that…" (see Table S1).

Following this approach, ancient sources are divided in three groups: (1) sources of the fourth-century B.C., (2) older sources apparently cited by authors of the Roman period, (3) sources of the Roman period. Data are summarized in Table 1 and Table S1.

Fourth-century B.C. sources (nearly contemporary to the alleged disaster)

The only directly known source for an earthquake in 373 B.C. is Aristotle, who mentions only an earthquake and a tsunami in Achaia at the time of a comet. Aristotle mentions the term "earthquake" about 40 times, with notices of other highly destructive earthquakes, but from his overall text, that earthquake in Achaia is not regarded as an event with spectacular destructive impacts, nor Helike is mentioned.

All other sources of the period (fourth- to third-century B.C.), especially Xenophon who covered the area and the period and in about 371 B.C. was in nearby Corinth, do not mention any destructive effects to Helike, as Petropoulos (1983) first noticed. The loss of the leading town of the area should have been an event with important military and political impacts and could not have been ignored, at least by Xenophon.

Some investigators refer to an ancient book named "de Mundo," assigned to Aristotle, in which a vague reference to the loss of Helike and Boura is given. This is not a genuine text; it is a text produced by later authors, known as pseudo-Aristotle, who were imitating Aristotle's style (Forster, 1914). This was a practice very common since the Roman times, and imitations of various ancient authors are known (pseudo-Plutarch, pseudo-Callisthenes, pseudo-Democritus, pseudo-Augustine, etc.). Guidoboni et al. (1994), for instance, include at least four ancient sources with prefix "pseudo."

References to ancient Greek authors by later authors

The texts of the Roman period which seem to cite ancient Greek authors referring to the loss of Helike (Table 1) should be treated with much care. This is because the original Greek texts to which they refer are not available, and because in many cases citation of older texts in antiquity was based on texts orally presented and discussed during symposia (for example, during the Plutarch's Table Talk; Klotz and Oikonomopoulou, 2011), so that an older text could be easily corrupted. Since catastrophic scenarios for Helike can be excluded, the following comments can be made for this group of texts in a "supervised learning" approach.

Strabo 5 (Table 1 and Table S1) refers to Eratosthenes using the expression "Eratosthenes said («φησί» in ancient Greek) that he observed submerged ruins in Helike and ferrymen crossing the submerged area after the disaster." This gives the impression that Strabo was citing Eratosthenes but this is out of place for the topography of the area. The problem is solved if the term «φησί» is changed to «φασί», meaning "it is said that Eratosthenes," and which should be translated as "rumors are spreading that Eratosthenes ...." This would indicate not a direct citation of Eratosthenes but a later legend or rumor, using the name of Eratosthenes to give some emphasis on the legend because Eratosthenes was a figure of influence in many fields; among others he was the first to measure with accuracy the radius of the Earth. A similar correction from «φησί» to «φασί» is suggested also for the text of Strabo 6 referring to Heracleides, a name referring to several ancient Greek authors. This change makes the text of Strabo consistent with texts of other authors of the Roman period who refer to Helike using the expression «φασί» (e.g., Pausanias 6, Aelian 1). It is quite possible that the proposed original term «φασί» was corrupted to «φησί» by later scribes, a problem common in antiquity (Sánchez Vendramini, 2018) and in texts referring to Helike.

Seneca 6 refers to the fourth-century writer Ephorus. A careful examination indicates that Ephorus was not making any reference to Helike, but rather he was only arguing that a certain comet was split in two. Seneca criticized him for this argument, "because it is widely known that this comet caused drowning of Helike and Boura." Hence, it is Seneca who indirectly introduced the connection between an earthquake in Achaia and a comet mentioned by Aristotle and the alleged destruction of Helike (Wickersham, 1994).

Seneca refers three times to the fourth-century historian Callisthenes as the source of information for the loss of Helike and Boura. Callisthenes is supposed to have written a treatise about the loss of these two towns (Seneca 1), relating their loss to a comet (Seneca 3, 5). Callisthenes work has been lost, but his book on the expedition of Alexander the Great against Persia, manipulated, if not fully rewritten by later authors, became very popular in various regions and languages until Medieval times; it is currently known as the work of pseudo-Callisthenes (Merkelbach, 1977; Bosworth, 2016). It is likely that Seneca was misled by the later text by pseudo-Callisthenes because it fit his ideas about comets.

In summary, no genuine, reliable information about the loss of Helike is offered by ancient Greek authors cited by authors of the Roman period.

Independent sources of the Roman period

Several authors of the Roman period discuss the loss of Helike, though with many differences (Table 1 and Table S1). A majority of these authors repeat a legend, some providing religious information about punishment of the sinful cities; only the text of Pausanias is a report of his visit in the area more than 500 yr after 373 B.C. Of interest are some verses (by Philo, Orosius, Bianor; Table 1) that indicate that Helike had become an empire-wide legend. On the contrary, a catalog of Roman towns includes Helike and Boura as towns in the hinterland and provides their coordinates (for details, Rizakis, 1995, p. 284). These reports are summarized in thematic units in the following paragraphs.

Birth of the legend. Helike was among several other towns of the region that disappeared as town states during a period of instability before the Roman times (Hellenistic period) and during the early Roman times (Karambinis, 2018). According to later sources (Strabo 6 and Pausanias), the land of Helike was annexed (usurped?) by Aigion. This information may conceal an explanation for the decay of Helike. The first surviving reference to the legend of the loss of Helike in the Roman period is due to Polybius, who died in about 120 B.C. This means that this legend existed in the early Roman period in Greece. What fed this legend is not known, but the legend of punishment by Poseidon was an easy explanation for the disappearance of the major town because of political and social reasons (Mackil, 2004).

Comet and earthquake. Comets were benchmarking events in antiquity, and Aristotle 1 reported a combination of a comet with an earthquake and a tsunami in Achaia, but he did not mention Helike, nor any major impacts in the wider area (Achaia). This combination of comet and earthquake was essentially forgotten in the following centuries, indicating that the Aristotle earthquake was ignored by later authors. Diodorus 1 and 2 mentioned a comet, but not related to Helike. About 100 yr later, Seneca 5/6 discussed this comet and manipulated ancient texts because he wanted to reject the hypothesis of Ephorus for a comet split in two, and in fact, he introduced a connection between the comet, Aristotle's earthquake, and the loss of Helike and Boura (Wickersham, 1994).

Geography of the area and submerged ruins. References to Helike in the Roman period are vague, and only two authors provide much information about Helike and Achaia.

Strabo, a major source for information for the Peloponnese about 400 yr after 373 B.C., did not have any personal experience of the area (Weller, 1906). Hence, his references to Helike are likely to reflect information and a legend that existed during his times.

Pausanias, on the contrary, visited the area more than 500 yr after 373 B.C. and provides a detailed and reliable description of what he saw and what people reported to him. Pausanias was shown the area of ancient Helike, in which he observed no traces of the ancient town, and this is reasonable because classical remains were buried by deltaic sediments at this time. He was perhaps also shown what was regarded as submerged remains of Helike. Apparently, Pausanias found no satisfactory evidence of submerged ruins, and his response was presented in a diplomatic way: he stated that the remains of Helike are not as clearly visible as in the past (see Faraklas, 2001).

Crime and punishment of Helike in the context of the ancient Greek World. Punishment of Helike and Boura by Poseidon is reported by four different authors, but for four different crimes: impiety to gods (crime "A"; Diodorus 1), disobedience of Helike to a decision of a council of confederated town states (crime "B"; Strabo 4), killing of suppliants from Asia Minor (crime "C"; Pausanias 1), and killing of a suppliant woman from the modern Greece mainland (crime "D"; Polyaenus).

The differences in the crimes leading to punishment are remarkable, culminating with the killing of suppliants, the most severe crime in ancient Greece. No convincing explanation for such a crime is given, although the punishment was severe in comparison with the punishment of Athens and Sparta for similar crimes. Hence, the core of the story is very diffuse and weak.

Contradictions in ancient texts concerning Boura. Various modern investigators have noticed major contradictions in the legend of the 373 B.C. earthquake, especially concerning Boura, the loss of which has been characterized as an exaggeration (Guidoboni et al., 1994).

Helike and Boura were punished for the same crime. Helike was supposed to have disappeared forever, but Boura only temporarily because it appeared again on the scene 70 yr later (Diodorus 3) and soon became an important town (Polybius), reconstructed by those who were away during the calamity (Pausanias 4). Furthermore, Boura is described by various ancient authors as having been submerged in the sea, although it was a town in the mountains. Some ancient authors alternatively suggest that it was lost in a "chasm" of the ground, which is impossible for a town state (see earlier). Aigeira, a third town farther east (Fig. 2), was also supposed to have been submerged during the same earthquake (Philo).

To reconcile this contradictory information, Stylianou (1998) proposed that both Boura and Aigeira included a harbor with the same name and that only their harbours were submerged in 373 B.C., whereas the main towns remained above sea level. Still, the remains of the harbour of Aigeira have been identified since long above the water, and in fact this harbor was uplifted by earthquake faulting, not submerged (Stiros, 1998). Similarly, the harbor site of Boura, brought to light by recent excavations (Fig. 4a), shows no sign of submergence; on the contrary, it is also located in an area of rapid uplift (Stewart and Vita-Finzi, 1996; Pirazzoli et al., 2004).

Helike and Boura as existing Roman towns. Not all sources of the Roman period regard Helike and Boura as lost towns. Pliny, a reliable author with experience in natural disasters (Plinian volcanic eruptions bear his name), reported that the two towns existed in his days, refounded by survivors of the disaster (Pliny 2). Furthermore, the list of Roman towns by Claudius Ptolemeus includes Helike and Boura as existing towns in the hinterland and even gives their coordinates (see Rizakis, 1995, p. 284). This strong evidence is usually ignored. Helike, however, is not shown in Tabula Peutingeriana, a thematic map of the late Roman World, surviving in a copy of the Medieval period (see fig. 4 in Stiros, 2020a).

Reliability of certain ancient texts. Some of the texts of the Roman period are unlikely to have any historical significance. For example, the text of Aelian, shown at the beginning of this section, was part of a book with oddities and imaginary stories on animals, written by the author to entertain his audience.

Discussion

In the first part of this study it was shown that the physical loss of Helike and of Boura during an earthquake was not possible, and recent geoarchaeological and archaeological studies confirm this result. Hence, Helike is simply one of the ancient towns that disappeared (Hansen and Nielsen, 2004, index 20; Karambinis, 2018), probably because of political, social, and military reasons. However, Helike represented a unique case because the remains of its Greek period had been rapidly buried by deltaic sediments, and they could not be seen during the visit by Pausanias in the area 500 yr after 373 B.C. (Pausanias 1/2/3). In fact, the first remains of Helike were brought to light only recently (see earlier, Fig. 4). The main problem is hence to explain whether and why ancient texts report a catastrophe that never occurred.

In the second part of this study, working in a kind of supervised learning, that is, excluding a major geomorphological change (and a catastrophe) in 373 B.C., it was possible to reevaluate ancient texts using a new approach. Ancient texts were regarded as a function of time since 373 B.C., and in addition, genuine texts were separated from rumors and forged texts. The conclusion of this analysis is that Aristotle reported an earthquake and tsunami in Achaia in 373 B.C., correlating with a comet, but he made no mention to any disaster of Helike because no such disaster took place. Certain texts or later references to ancient Greek authors that seem to mention the loss of Helice are later forgeries (e.g., by pseudo-Aristotle) or were manipulated. In fact, the first mention of the Helike legend was made in the early Roman period by Polybius. The comet that correlated with the earthquake in Achaia according to Aristotle was ignored by all other later authors except for Seneca (Table 1). In fact, Seneca introduced the connection between the legend of the loss of Helike with Aristotle and the comet only to strengthen his theory about comets.

The Helike legend became very popular in Roman times for certain good reasons. It was reminiscent of ancient Greek traditions of god punishment that were in fashion in Roman times. It provided an easy explanation for the disappearance of an important ancient Greek town, and it had a convincing physical background: ancient Greek remains were invisible, buried by deltaic sediments, and remained buried until recently, feeding the modern legend of the loss of Helike by Marinatos (1960); that is, another neocatastrophism theory (Ambraseys, 2006). It is also possible that certain natural concretions and biological structures on the sea bottom that gave the impression of building remains (compare with Andrews et al., 2016) had contributed to the formation and longevity of the legend. In fact, until about 30 yr ago, local people liked to point out offshore features that they mistakenly called submerged ancient remains.

Another main reason for the popularity of the legend of Helike in an empire-wide scale is that the Helike area was located in a prominent position in the seaway between Rome and the eastern provinces of the Roman empire, near the western entrance or exit of the Gulf of Corinth (Fig. 1). Hence it was visible to sailors and travelers eager for a nice story during and after a long trip.

What is interesting, however, is that the legend of destruction of Helike became popular, whereas the "true" destruction of the uplifted Aigeira harbor (Stiros, 1998, and references therein) and especially of the submergence of the Kenchreai harbor (for location, see Figs. 1 and 2), critical for the connection of Rome with the eastern part of the empire, were ignored by ancient authors (Stiros, 2020b). The Aigeira uplift, however, may have been recorded as subsidence (Philo report, Table 1).

Possible archaeoseismomological evidence

Archaeological excavations have brought to light ancient remains in the Helike area that may testify to ancient earthquakes. The inferred destruction of an archaic temple next to the older temple of Figure 4a may testify to a fourth-century B.C. earthquake. An earthquake is inferred to have damaged another archaic temple, dedicated to Artemis (Diana), in Ano Mazaraki between 400 and 350 B.C. (for location, see Fig. 2; Petropoulos, 2012). Destruction layers in the Boura harbor may also testify to two earthquakes, approximately in 290 and 230 B.C. (Kolia, 2018). However, because all of this evidence is still fragmentary and because earthquakes are and were frequent and "local" in Achaia (see Aristotle 1.6.368b and Seneca 7), the study of these possible archaeology-derived earthquakes is a future task.

Implications for the tsunami mentioned by Aristotle

The results of sedimentological analyses (Kortekaas et al., 2011; Engel et al., 2016) tend to exclude the possibility of a significant fourth-century B.C. tsunami in the wider Aigion area. This result can be used as a constraint to understand Aristotle text. His text is unclear (Table S1), and with modern knowledge, it can be read in two ways: (1) the great comet rose from the SW, about the same time with the Achaia earthquake and the wave invasion; (2) the great comet rose from south, at the same time with the Achaia earthquake and the wave invasion from the west. This second alternative means that the tsunami had hit not the Gulf of Corinth, but the western coast of Achaia, the Patras area, which is exposed on the west to the open sea (Ionian Sea); this part of Achaia was too poorly developed before the Roman period (Rizakis, 1995; Petropoulos, 2012) to deserve a mention of towns damaged by the tsunami and the earthquake reported by Aristotle.

Implications for Historical Seismology

Results for Helike do not question the value of reliable ancient texts reporting earthquakes. They only indicate a necessary distinction between two different types of information:

1. vague, dramatized information, mostly by much later sources and with religious character, may not reflect natural events and disasters, especially because such concepts were intrinsic in the ancient Greek religion and culture (Leveau, 2005).

2. ancient reports, especially by contemporary authors describing specific events, provide reliable seismological information. For example, concurring events (an earthquake during a military operation or during a visit of a certain authority in an area) or reports of seismic damage, especially of temples and aqueducts, occasionally supported by excavation evidence (e.g., Stiros, 2020c) or repairs and support for recovery of towns from seismic damage (Guidoboni et al., 1994; Ambraseys, 2009) represent reliable reports of earthquakes and evidence permitting reconstruction of some of the earthquake parameters.

Data and Resources

The source of all data used is indicated in References. Ancient texts discussed were obtained from searches in the Library of the British School of Archaeology at Athens, the Loeb Classical Library (www.loebclassics.com/, last accessed July 2021), and the Perseus Digital Library (www.perseus.tufts.edu/hopper/, last accessed July 2021). The website of the Topostext Foundation (www.topostext.org, last accessed August 2021) was consulted. Figures were based on material obtained from Google Maps, from the Geographical Service of Greece (www.gys.gr, last accessed August 2021) on ESRI background or provided by the excavator, E. Kolia. The supplemental material for this article includes Table S1 with excerpts of ancient texts of Table 1 and Table S2, which explains archaeological and historical terminology.

Declaration of Competing Interests

The author acknowledges that there are no conflicts of interest recorded.

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Nuclear bomb tests as a cause of climate change: a novel conceptual model

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Abstract

A model of climate change is proposed considering that the current unprecedented high concentration of carbon dioxide in the atmosphere cannot be explained only through anthropogenic carbon dioxide (CO_2) due to land-use change and fossil fuel burning. An additional source is envisaged, due to the high CO_2 Ocean intake, of the same order of magnitude as anthropogenic CO_2, as recently revealed. Upwelling currents are proven to be essential sources of CO_2 and among them, the Antarctic Circumpolar Current (ACC) is the most significant. Furthermore, it is supported that Nuclear Testing in the 1950-1960s has disturbed deep waters rich in sequestered CO_2 and caused the circulation of CO_2 along the network of oceanic currents, the global conveyor belt. Upwelling along the Antarctic Circumpolar Current of deep water from the Pacific, the Indian and the Atlantic Oceans is believed to be a major source of CO_2.

New features presented in this article are

- the abrupt and vigorous change of the climate since the Nuclear Testing, associated with steady temperature increase and modification of the carbon cycle
- the outrageous rate of atmospheric CO_2 increase, five times higher than similar extreme events in the geological past,
- the function of the Southern Ocean both as sink and a source of CO_2 with outgassing prevailing currently,
- the heat engine along the magmatic boundary of the Antarctica Lithospheric Plate which stimulates upwelling of the ocean currents and causes warming of the West Antarctic climate, since the Nuclear Testing.

1. Introduction

Summarizing his guidelines on the change of late Quaternary climate, W.S. Broecker (2000) observed that changes were vast and, in many cases, happened abruptly. They were triggered by reorganizations of the ocean's thermohaline circulation, but every element of the global climate system was involved. Referring to the modern climate research he proposed that "clearly, the challenge is to come up with conceptual models capable of explaining the changes recorded in ice and sediment and then to test these scenarios through the use of climate models". As revealed by Graven et al. (2020), the geochemist Wally Broecker, who pioneered many radiocarbon applications, used to say, "Instead of publishing papers, we should have just dropped everything and collected samples all over the world." Fortunately, this has recently become a standard practice in the more hostile area of the planet, the Southern Ocean in Antarctica, through arrays of profiling floats recording meteorological and biochemical parameters from the sea surface to a depth of two kilometers currently.

The evidence for the climate change predominantly is based on measurements of the mean annual global temperature and the increase of the carbon dioxide in the atmosphere and the oceans. Multiple time series are correlated, including the temperature, the greenhouse gases, the isotopic values of the radiocarbon (^{14}C), and the stable isotope ^{13}C. It is revealed that the increase of temperature and the sharp changes in the carbon cycle start during the short Nuclear Testing period, approximately in 1950s to 1960s and this is not considered as a mere coincidence.

Recent meteorological and geochemical research in the Southern Ocean, supported by modeling applications, created a new basis for reexamining the causes of climate change, since there is currently convincing evidence that the Southern Ocean could be an active source of carbon dioxide, whilst it is used to be considered so far as a safe sink.

The climatic impact of carbon dioxide from fossil fuels is not underestimated although it was considered that, at least until the middle of the twentieth century, CO_2 was taken up by the ocean. Based on carbon isotopic study from wood, marine material, and terrestrial plants Ravelle and Suess (1957) concluded that "most of the CO_2, released by artificial fuel combustion since the beginning of the industrial revolution must have been absorbed by the oceans. The increase of atmospheric CO_2, from this cause, is at present small, (314–315 ppm in 1958 after Nakazawa, 2020), but may become significant during future decades if industrial fuel combustion continues to rise exponentially".

The abrupt character and extreme trend of the unprecedented CO_2 increase is emphasized in this article as unparalleled in the last million years, highlighted as the major cause of concern. In particular, the possibility is examined in this article whether the recent Nuclear Testing detonations resulted in the release of carbon dioxide previously sequestered in deep oceanic waters, transferred to the surface through the global overturning circulation in the oceans, the so-called "conveyor belt". If there is a "leakage" of carbon dioxide through the global conveyor belt from the major reservoir of carbon dioxide on the planet, the oceans, then the climatic crisis is much more severe than thought due simply to the greenhouse effect.

2. Revisiting the evidence of climate change

The ongoing climate change has been documented based on time series of temperature and carbon dioxide measurements which are reexamined here in the light of the latest results. Conventionally, a set of essential climate variables is monitored in meteorology which consists of 54 different variables (16 atmospheric, 19 oceanic, and 19 terrestrial) in the Global Climate Observing System, as summarized by Trewin et al. (2020), a fact that indicates the complicated nature of the climate. However, in regional studies the number of climate variables applied can be significantly reduced.

2.1 Temperature trend in the last centuries

The evaluation of the temperature evolution in the industrial era will be better highlighted in the context of our immediate climatic past, the Little Ice Age (LIA). Matthews and Briffa (2005) highlighted the Little Ice Age both as a glaciological and as a climatic concept, in the light of new data on the glacier and climatic variations of the last millennium. They also evaluated that 'Little Ice Age' glacierization occurred over about 650 years and can be defined most precisely in the European Alps (c. AD 1300–1950). 'Little Ice Age' climate is defined as a shorter time interval of about 330 years (c. AD 1570–1900) when in land areas in the Northern Hemisphere, north of 20°N, prevailed summer temperatures significantly below the AD 1961–1990 mean. They have also shown for the first time in map form, that the LIA was a global phenomenon, not merely a European one.

Furthermore, carbon isotopic values from tree rings from different sites around the world (Pazdur et al. 2007) confirm the climate cooling during the periods of lower sunspots of the Maunder minimum (1645–1715) and the Dalton minimum (1790–1820). As suggested by Oliva (2018) a combination of large volcanic eruptions and lower solar irradiance favored summer cooling in the Northern Hemisphere, which was amplified by feedback processes, such as the increase of sea ice extent in the Arctic. In a Special Issue of the Cuadernos de Investigación Geográfica magazine (Geographical Research Letters) edited by Oliva (2018), intriguing research articles highlight a wide range of topics on LIA, the climatic background of the twentieth century. It is clarified therefore that the current global warming succeeds a period of cooling over the Northern Hemisphere.

In a recent report by IPCC (2018) the mean temperature change over the period of instrumental observations is expressed as departure from 1850–1900 (Figure 1).

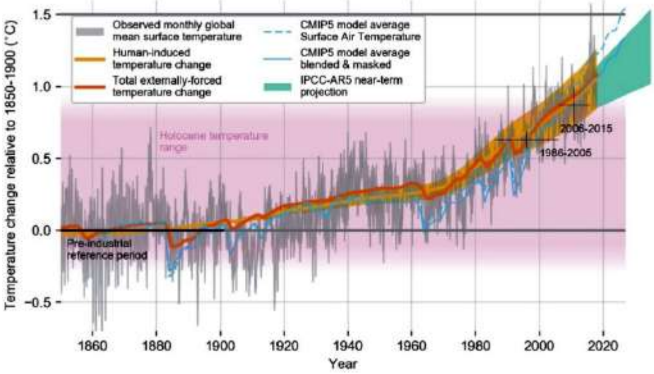

Figure 1. Evolution of the global mean temperature over the period of instrumental observations. Source: IPCC (2018).

Morice et al. (2020) reevaluated surface temperature data since 1850 by combining new input data sets and statistical analysis. Their results indicate greater warming of the global average over the course of the whole record, ascribed to an improved representation of Arctic warming and a better understanding of evolving biases in sea surface temperature measurements from ships (Figure 2).

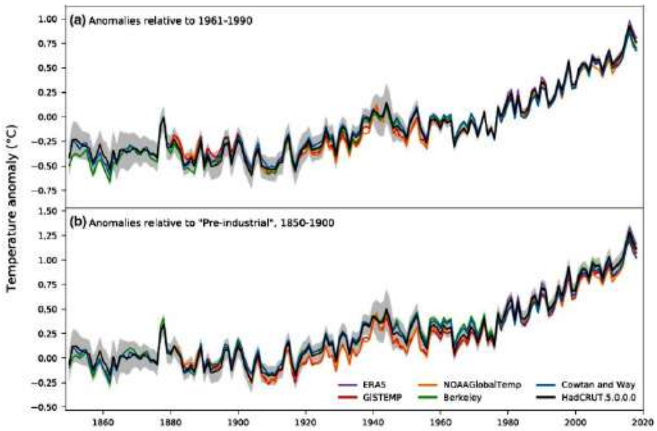

Figure 2. Global annual mean temperature difference from the pre-industrial conditions (1850-1900) for five data sets (Source: Morice et al. 2020: figure 8b).

It is noted that in both relevant plots a clear trend of increase of the mean global temperature is depicted since 1960. Despite that, different spatio-temporal patterns across the world may occur due to local forcings, either volcanic, solar, or oceanic. A typical example is the so-called warming hiatus over some regions where the annual mean temperature consistently exhibits a cooling phenomenon in the period 1998-2014 (Wangfl and Liu 2020; Liu et al. 2018). In Northeast China in particular the trends of Tmax, Tmin, and Tmean are negative (Sun et al. 2017). As correctly noted in the IPCC report (2013: 38), despite the robust multi-decadal warming, there exists substantial interannual to decadal variability in the rate of warming, with several periods exhibiting weaker trends, including the warming hiatus since 1998.

It is corroborated that when moving from the global to the regional scale a spatio-temporal variability of the temperature is expected, a measure of which is given by the diligent evaluation of measurements over Spain for the period 1916-2015. The annual mean temperature evolution has not followed a monotonous trend, and instead, four periods can be identified: (1) rising until ca. 1950, (2) pause-stagnation-cooling between 1950 and 1970, (3) second warming between 1970 and 1990, and (4) a second pause until 2015. At the same time, this is also a measure of the uncertainty in projecting temperature measurements for a century in the future.

2.2 The CO_2 trend in the atmosphere

The current excessive level of carbon dioxide in the atmosphere requires undeniably the major concern in regard with the climate change and the possible biological implications. In the influential documentary film "An Inconvenient Truth" on the United States Vice President Al Gore's campaign on global warming, the scientific evidence is correctly based on the current excessive concentration of carbon dioxide.

Collections of air samples at the Mauna Loa Observatory, Hawaii (Keeling, Bacastow et al. 1976) and at the Southern Pole (Keeling and Adams 1976) started in 1957, to document the effects of the combustion of coal, petroleum, and natural gas on the distribution of CO2 in the atmosphere. The rate of rise has not been steady, it declined in the mid-1960s and accelerated thereafter (Figures 3 and 5). Similar rate changes have been observed at the South Pole and evidently, a global phenomenon is recorded.

The ongoing increasing trend of the carbon dioxide measurements at the Mauna Loa Observatory in Hawaii, the so-called Keeling curve is shown in Figure 3; it is the most vigorous evidence of an anomalous situation, since the recorded values increased by more than100 ppm in sixty years, at levels significantly higher than at any time during the past 800,000 years, as deduced from Antarctic ice cores.

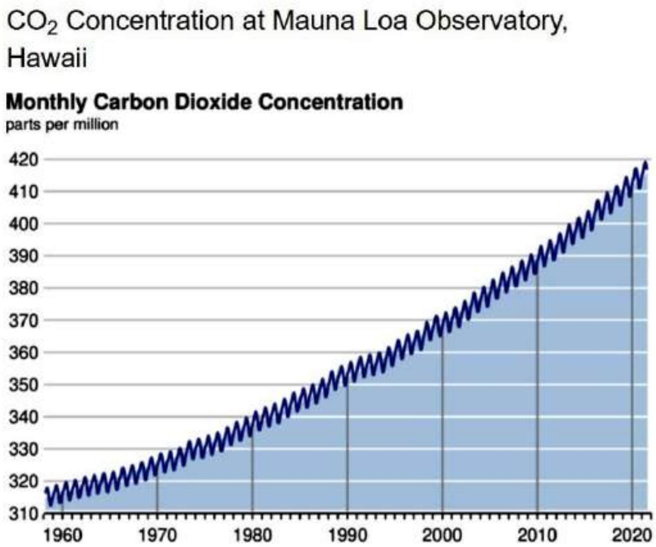

Figure 3. The Keeling Curve. Source: Scripps CO_2 Program: Sampling Stations. https://scrippsco2.ucsd.edu/

O'Connor (2020) compiled measurements of the CO_2 concentration in the atmosphere based on Law Dome and Siple ice cores from Antarctica and direct measurements at Mauna Loa. He observed that these data demonstrate that the carbon dioxide concentration has been increasing steadily since 1750 and this increase has also accelerated significantly since 1960.

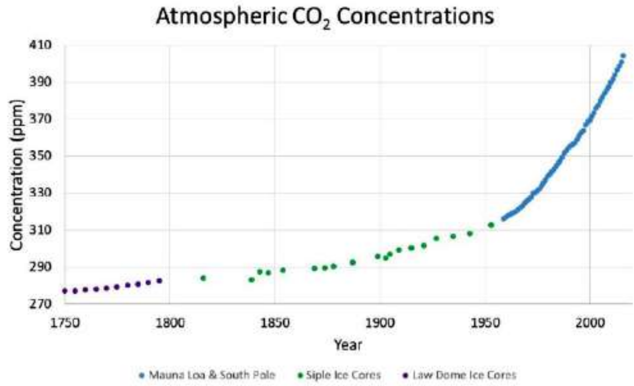

Figure 4. Compiled observations of atmospheric CO_2 concentrations (O'Connor 2020).

2.3 Combined carbon isotopic and tree-ring measurements

The earlier carbon dioxide trend, before the Keeling curve, can be decoded from proxy indicators like the ice cores and the tree rings, and for a short interval from the isotopic direct measurements in New Zeeland. Turnbull et al. (2017) presented a 60-year record of atmospheric radiocarbon dioxide ($\Delta^{14}CO_2$) measurements from Wellington, New Zealand. The measurements, the first in the world, were started at Wellington, New Zealand in 1954 with the aim to better understand the carbon cycle (Figure 5). Fortunately, the Wellington time series covers the history of atmospheric Nuclear Testing, the so-called "bomb spike" and the subsequent decline in radiocarbon. The bomb spike maximum is higher and one year earlier in the Northern Hemisphere records consistent with the emission of most bomb ^{14}C in the Northern Hemisphere.

Nuclear tests contributed to the radiocarbon rise first in the 1950s; then a hiatus in testing led to a plateau in Wellington $\Delta^{14}CO_2$ (Figure 5). A series of very large atmospheric nuclear tests in the early 1960s led to further increases of radiocarbon in the atmosphere. Most atmospheric nuclear weapons testing ceased in 1963, but the Wellington record peaks in 1965 when it begins to decline, at first rapidly in the 1970s and gradually slows after 1990.

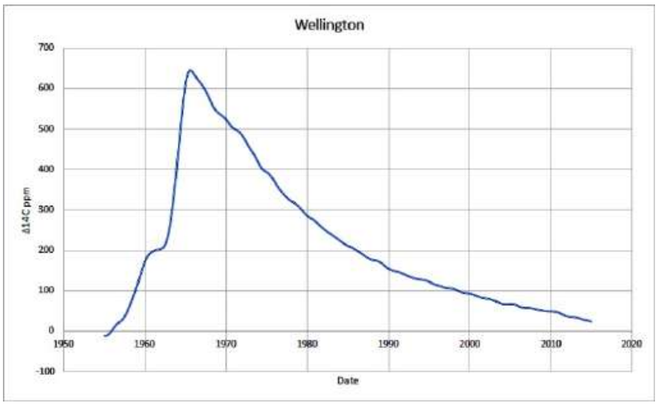

Figure 5. Wellington $^{14}CO_2$ smooth curve fit to the final dataset (projected from the supplementary data given by Turnbull et al. (2017)).

Global high-precision atmospheric $\Delta^{14}CO_2$ records covering the last two decades are presented and evaluated by Levin et al. (2010) in terms of changing (radio)carbon sources and sinks. Direct measurements were again combined with tree-ring data to produce a plot with a clear time-lag of the Southern Hemisphere and a higher record in the Northern Hemisphere.

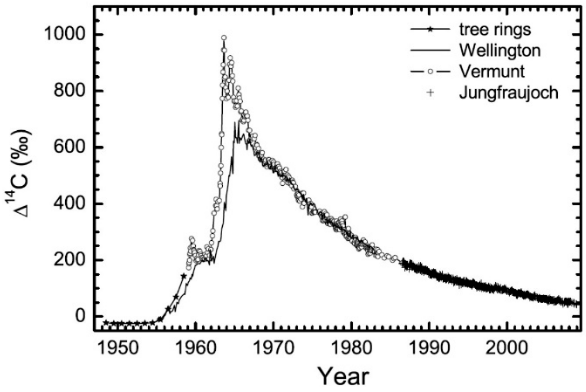

Figure 6: Temporal change of observed atmospheric $\Delta^{14}CO_2$ in the northern and the southern hemisphere (Levin et al 2010).

Tree-ring record of ^{14}C from the Altiplano plateau in the central Andes is combined with other ^{14}C records from the Southern Hemisphere during the second half of the 20th century (Figure 7). The tree-ring record faithfully captured the bomb signal of the 1960s with an excellent match to atmospheric ^{14}C measured in New Zealand.

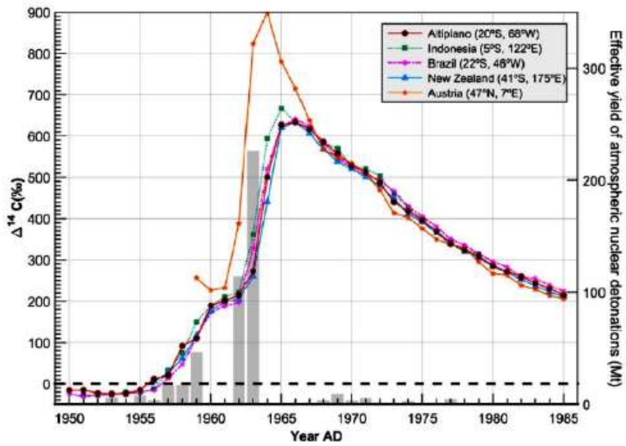

Fig. 7. The bomb-peak in ^{14}C is clearly recorded in the annual tree-ring data during the bomb-testing period (red line with black circles). The grey bars show the effective yield of thermonuclear detonations in Megatons during this period (Ancapichún et al. 2021).

Graven et al. (2017) compiled atmospheric datasets for $\Delta^{14}C$ and $\delta^{13}C$ in CO_2 over the period 1850–2015 with the aim to produce a standard atmospheric boundary condition for the ocean and terrestrial biosphere models simulating ^{14}C and ^{13}C. Variations in ^{13}C are reported as $\delta^{13}C$, which represents deviations in $^{13}C/^{12}C$ from standard reference material. For ^{14}C, the notation $\Delta^{14}C$ is used, which represents deviations from the Modern Standard $^{14}C/^{12}C$ ratio.

The isotopic composition in the carbon cycle has been strongly perturbed by human activities since the industrial revolution, indicated first by the slow decline of ^{13}C. Fossil fuel, depleted in ^{13}C and entirely depleted in ^{14}C is diluting the proportion of the isotopes ^{14}C and ^{13}C relative to ^{12}C in atmospheric CO_2. In addition, $\Delta^{14}C$ was also subject to a large, abrupt perturbation in the 1950s and 1960s when a large amount of ^{14}C was produced during the atmospheric Nuclear Testing period.

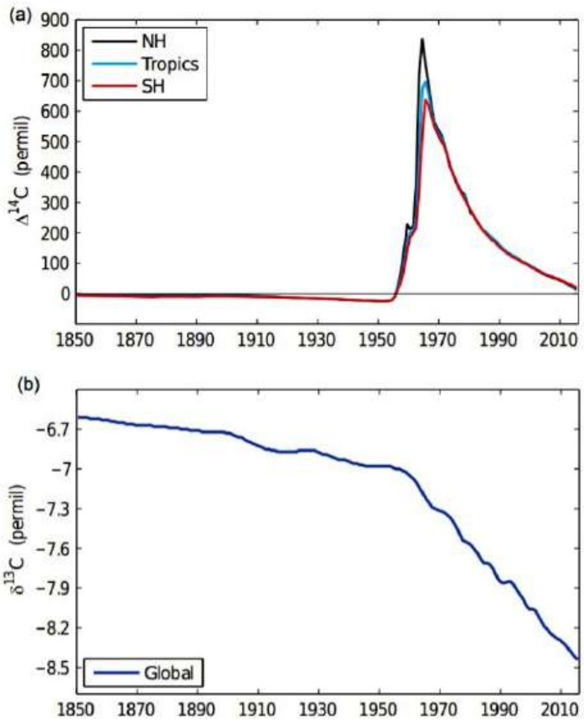

Figure 8. Atmospheric datasets for (a) $\Delta^{14}C$ in CO_2 and (b) $\delta^{13}C$ in CO_2. Annual mean values of $\Delta^{14}C$ and $\delta^{13}C$ are provided for three zonal bands representing the Northern Hemisphere (30°–90° N), the tropics (30°S–30°N), and the Southern Hemisphere (30°-90° S) (Graven et al. 2017).

2.4 Estimation of atmospheric CO_2 from ice cores

Determinations of ancient atmospheric CO_2 concentrations for Siple Station (West Antarctica) were derived from measurements of air occluded in a 200 m core drilled at Siple Station in the Antarctic summer of 1983–1984. The CO_2 record extends over the industrial revolution with circa 280 ± 5 ppm in 1750, increasing gradually to 345 ppm in 1984 (Neftel et al. 1994). Ice cores from Greenland and Antarctica were analyzed in two laboratories for comparison, the results found are in good agreement and cover the period after 900 AD. A pre-industrial value of 280 ppm is confirmed during the 18th century and the record indicates the anthropogenic increase since 1800 AD (Barnola et al. 1995).

A continuous record of atmospheric CO_2 from 1006 AD to 1978 AD has been derived from three ice cores from Law Dome, Antarctica (Etherige et al. 1996). Pre-industrial concentrations are in the range 275-284 ppm with the lower level during 1550 AD – 1800 AD probably as a result of the colder global climate during the Little Ice Age. CO_2 growth is observed in the ice core record in 1800 AD with the onset of the anthropogenic disturbance, due to land-use change and coal burning.

The yearly mean CO_2 mole fraction increased from 314–315 ppm in 1958 to 403–407 ppm in 2017, indicating a time-dependent growth rate from 1.0 ppm per year during 1958–1960 to 2.6 ppm per year during 2015–2017 (Nakazawa, 2020).

The major atmospheric greenhouse gases (CO_2, CH_4, N_2O) from revised ice core records and new measurements covering recent centuries are presented in Figure 10 by Rubino et al. (2019). These records come from Law Dome, Antarctica, South Pole, and several sites and have been measured in several laboratories around the world. The combined correlation of N_2O, CH_4, CO_2, and $\delta^{13}C$ allows the distinction of three periods: 1750-1830 AD, 1830-1960, and 1960 to date.

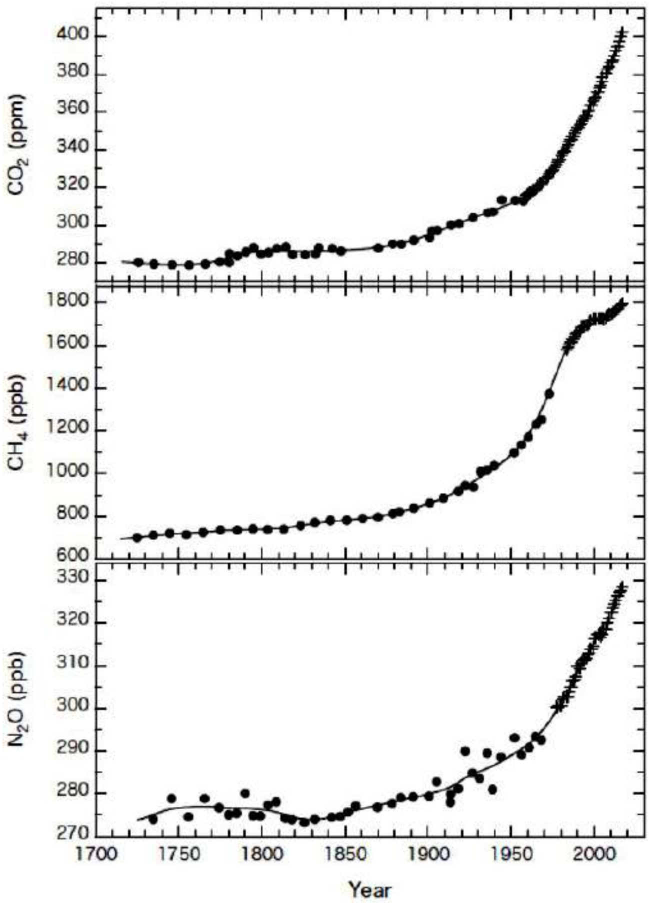

Figure 9. Variations of atmospheric CO_2, CH_4 and N_2O from Antarctic ice core and observations from the South Pole, and Australia (Nakazawa, 2020).

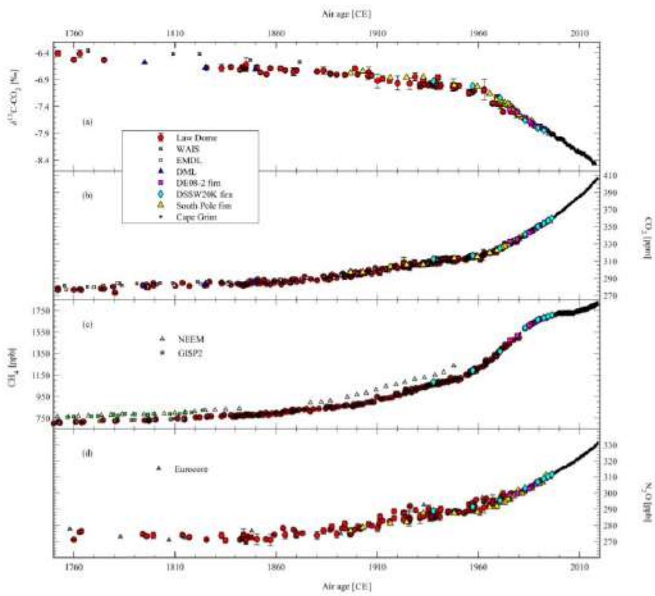

Figure 10. Revised records (1750–2010 AD) of (a) ^{13}C-CO_2, (b) CO_2, (c) CH_4, and (d) N_2O from Law Dome ice and firn compared to the South Pole firn records of ^{13}C-CO_2, CO_2, and N_2O and to published records from other sites (Rubino et al. 2019).

3. Carbon dioxide and nutrient fluxes in the Southern Ocean

3.1 The global carbon cycle

It has become an indisputable axiom that "the human perturbation of the carbon cycle is now well documented and agreed to be the principal cause of climate change. Anthropogenic perturbation of the global carbon cycle occurs via the release of fossil fuel CO_2 into the atmosphere, and via land-use and land-cover transformations. This perturbation induces a complex response of the natural carbon pools and fluxes, which together result in an increased atmospheric CO_2, the main cause of climate change" (Canadell et al. 2004).

No matter how elegant this definition, truly concise admittedly, it is rather deterministic and discourages the investigation of additional carbon dioxide natural sources, a task which is attempted here, particularly for the upwelling systems of the biggest oceanic current, the Antarctic Circumpolar Current (ACC). Without underestimating the Eastern Boundary Upwelling Systems (Siddiqui et al. in press), upwelling in the Southern Ocean provides the primary window for the global deep ocean to communicate with the atmosphere. It leads to the outgassing of CO_2 from nutrient and carbon-rich deep waters when exposed to the atmosphere, and conversely, ocean uptake of atmospheric CO_2 occurs in regions of freshwater formation from ice melting.

The main avenue of CO_2 flux is the biological pump, a wide suite of processes through which marine biota remove inorganic carbon dioxide from the sea surface and transfer it deeper in the ocean in the form of particulate biologically fixed organic tissues ("soft tissue") and associated carbonate minerals ("hard tissue"). Marine phytoplankton and heterotrophic microbes play an important role in the formation of Dissolved Organic Carbon (Wagner et al. 2020). Galbraith and Skinner (2020) define the biological pump to be all processes through which marine life interacts with the physical and chemical state of the ocean to alter the oceanic inventory of dissolved carbon relative to the atmosphere. By this definition, the biological pump depends equally on the ecosystem and on the physical processes that transport sequestered carbon and mediate air–sea exchange.

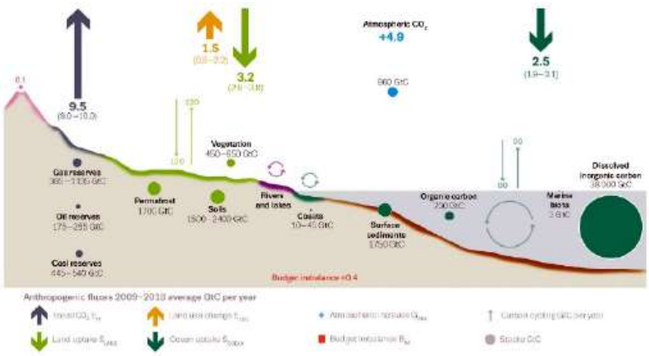

Figure 11. Anthropogenic disturbances (thick arrows) on the global carbon cycle, averaged for the decade 2009–2018 in GtC/yr, along with the updated carbon stocks in the major reservoirs, in GtC, schematically given by Friedlingstein et al. (2019).

The dominant role of the oceans in the carbon cycle is obvious from the global mass of the major carbon reservoirs which is estimated as follows: 590 Gton in the atmosphere, 900 Gton in the surface ocean, 2,000 Gton in the terrestrial biosphere, 3,000 Gton in reactive marine sediments and 37,100 Gton in the intermediate and deep ocean of which 36,400 inorganic and 700 Gton organic (Lee et al. 2020: 337).

Schematic representation of the overall perturbation of the global carbon cycle caused by anthropogenic activities, averaged globally for the decade 2009–2018, in GtC/yr, along with the carbon stocks in the major reservoirs, in GtC, are given in Figure 11 after Friedlingstein et al. (2019). Anthropogenic emissions, fossil fuel and land use change, occur on top of an active natural carbon cycle that circulates carbon between the natural reservoirs. It is noted that the annual ocean uptake is seriously underestimated to 2.5 GtC/yr, as explained in the following discussion, and this opens the question for other CO_2 sources in addition to fossil fuel burning.

There are several known mechanisms for the ocean to store carbon dioxide and the biological pump is one of them. Carbon dioxide dissolution is another one, the "solubility pump," which produces Dissolved Inorganic Carbon, preferentially concentrated in colder, deeper waters of higher solubility. Thus, air-sea gas exchange and the temperature dependent solubility of CO_2 concentrate carbon in the cold polar waters that fill the deep ocean. The carbon dioxide disequilibrium at the sea surface-atmosphere interface triggers the exchange of carbon dioxide between the atmosphere and the ocean when ocean circulation and air-sea exchange re-equilibrate the dissolved carbon in the atmosphere. In conclusion, the ocean is the largest reservoir of carbon because of the high solubility of CO_2 in seawater, creating a large dissolved inorganic carbon pool, and due to biological processes that exchange carbon between the surface and the ocean.

3.2 Antarctic Circumpolar Current in the Southern Ocean

ACC is the strongest current system in the world oceans and the only ocean current linking all major oceans, the Atlantic, the Indian, and Pacific Oceans; it ventilates most of the world's ocean abyss and participates in the global carbon cycle. The full-depth volume transport has a mean of 141 Sv (standard error of the mean 2.7; one Sv equals 10^6 m^3/s) or about 141 times the transport of all the world's rivers combined (Koenig et al. 2014).

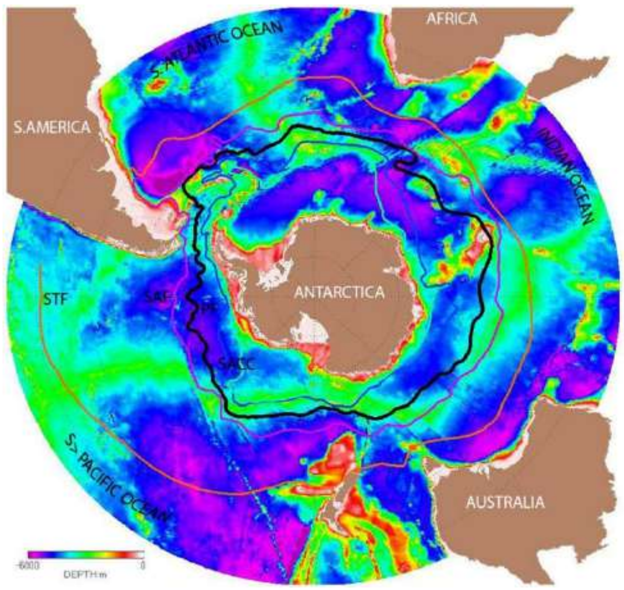

FIGURE 12. Mapped using Sea Surface Height, the mean Antarctic Circumpolar Current front positions are shown, color coded as follows: the southern boundary of the ACC blue (SAAC), the Polar Front black (PF), the southern ACC Front magenta (SAF), the Subtropical Front red (STF). Source: NASA, https://www.nasa.gov/vision/earth/lookingatearth/grace-images-20051220.html

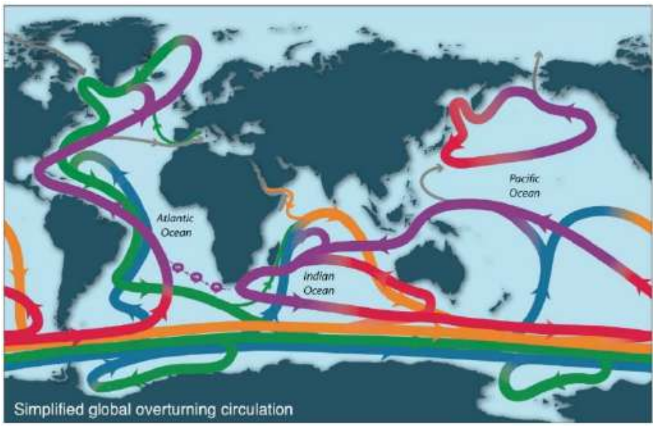

Figure 13. Schematic of the global overturning circulation. Purple (upper ocean and thermocline), red (denser thermocline and intermediate water), orange (IDW and PDW, Indian Deep Water and Pacific Deep Water), green (NADW, North Atlantic Deep Water), blue (AABW, Antarctic Bottom Water), gray (Bering Strait components; Mediterranean and Red Sea inflows). Source: Talley (2013).

The overturning pathways for the North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW) and the Indian Deep Water and Pacific Deep Water (IDW and PDW) are intertwined (Figure 14). All three northern-source Deep Waters (NADW, IDW, PDW) move southward and upwell in the Southern Ocean. Changes in the ocean overturn on decadal to millennial timescales are central to variations in Earth's climate. A 3D Schematic of the global overturning circulation ("GOC") is given by Talley (2013) in Figure 14. Each of the three oceans transports deepwater southward where it rises to the surface in the Southern Ocean, and each transports bottom water northward.

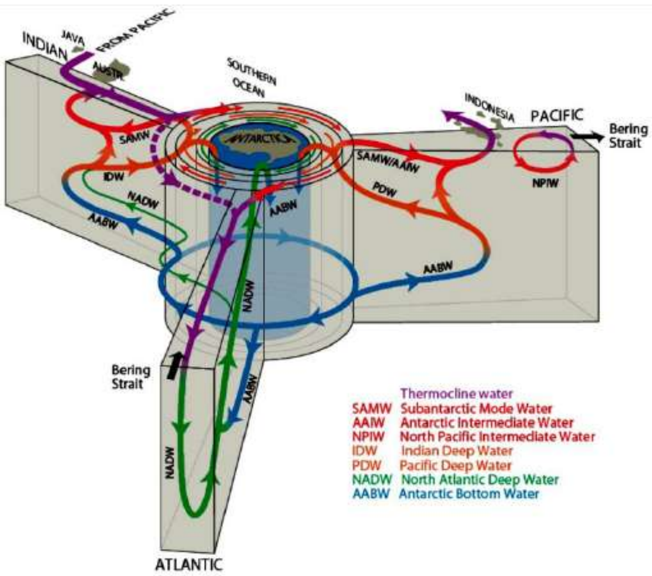

Figure 14. Schematic of the overturning circulation from a Southern Ocean perspective (Talley 2013).

Regarding the overturning circulations in the oceans, it is generally considered that "since there are no significant local deep heat sources in the world ocean, waters that fill the deep ocean can only return to the sea surface as a result of diapycnal eddy diffusion of buoyancy (heat and freshwater) downward from the sea surface" (Talley et al. 2011). However, Antarctica is a single lithospheric plate surrounded a continuous front of spreading and magmatic eruption on the sea floor and therefore an ideal environment for overturning circulation (Figure 15).

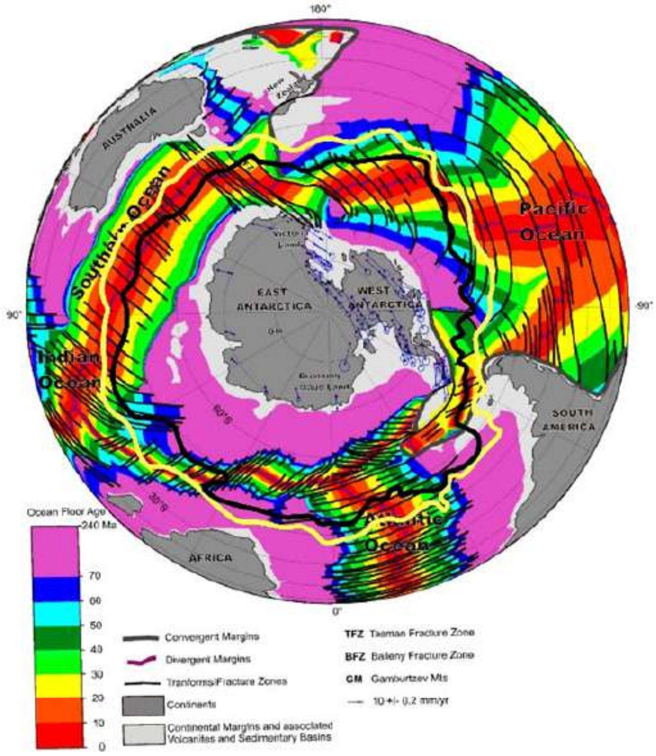

Figure 15. The Antarctica lithospheric plate, surrounded by young ocean floor, 0 to 10 Ma old. Black line: the polar front; yellow line: southern Antarctic Circumpolar Current. Adapted from Zanutta et al (2018).

Absolute plate velocities between the 140° E and 40°W, including Victoria Land and West Antarctica with the Peninsula, are around 10 mm/yr, trending around the 135° E meridian. Exceptionally, the general uplift in the Antarctic Peninsula and in the eastern part of West Antarctica is characterized by locations with movements exceeding 10 mm/yr and up to over 50 mm/yr. These larger values may easily relate to the active tectonics, including the presence of converging margins. In any case, the transmission of heat by convection and emanation of rich in metals hydrothermal solutions are expected along the spreading boundary of the Antarctic plate (Zanutta et al 2018), as well as along the continental margin and the associated volcanic activity shown in Figure 15.

It is therefore considered that the Antarctic Circumpolar Current is the surface expression of the oceanic ridge of the Antarctic tectonic plate, driven by both winds at the surface and heating at the ocean bottom by the oceanic ridge which acts as a heat engine of the upwelling currents. Furthermore, the interaction of the ACC with large and deep (>2500 m) topographic features, as the mid-ocean ridges, is recognized to generate intense upward movements (Sergi et al. 2020).

3.3 Carbon dioxide sinks and sources in the Southern Ocean

Observational studies of climatological, oceanographic, and biogeochemical nature have revealed in the last decades the predominant role of the Southern Ocean in the global overturning circulation, as well as in the carbon dioxide bidirectional exchange between the ocean and the atmosphere. The recognition of the Southern Ocean's crucial importance for the global carbon cycle and climate brought the Antarctic to the forefront of scientific interest. Due to poor intermittent observations and insufficient understanding of the outgassing mechanisms, the significance of the carbon dioxide sources was extremely underestimated in the 2010s, but the introduction of continuous robotic measurements revealed that the Southern Ocean is an essential source of CO_2, comparable to fossil fuel burning.

The first air-sea flux studies of CO_2 in the Southern Ocean are supported by inverse modeling and many campaigns of direct measurements. Mikaloff Fletcher et al. (2007) and Gruber et al. (2009) synthesized estimates of the contemporary net air-sea CO2 flux based on an inversion of interior ocean carbon observations. The first modeling results indicated that the outgassing of natural CO_2 south of 44ºS amounts to approximately 0.4 Pg/y of carbon, and, after Mikaloff Fletcher et al. (2007), this makes the Southern Ocean one of the largest sources of natural CO_2. However, this estimation of outgassing is recently revised significantly upwards.

Higher rates of CO_2 exchange more than two petagrams of carbon per year (2 Pg/yr) have been estimated by Watson et al. (2020). They pointed out that previous estimates of this flux, derived from surface ocean CO_2 concentrations, have not corrected the data for temperature gradients properly. They furthermore calculated a time history of ocean-atmosphere CO_2 fluxes from 1992 to 2018, corrected for these effects and this increased the calculated net flux into the oceans by 0.8–0.9 Pg/yr. It was, therefore, suggested that most ocean models underestimate carbon sink in the ocean.

Significantly higher rates are indicated from biogeochemical models. As described by Xing et al. (2020) carbon export from the atmosphere to the ocean is largely governed through biological processes whereby Particulate Organic Carbon, (POC), in the form of living cells or detritus, gravitationally settles across the boundary separating the surface mixed layer from the underlying mesopelagic waters, a process known as the biological gravitational pump (BGP). Current estimates of BGP export from global biogeochemical models are in the range of 4–9 Pg/yr; however, these estimates do not consider additional physically mediated export pathways that could significantly augment this export by increased wind mixing. Findings by Xing et al. (2020) show that carbon export to the ocean via these processes during winter occurs on time scales too short to be adequately sampled with the ~5–10 day profiling intervals. This can result in an underestimated carbon export, shrinking values by order of magnitude, or missing the process entirely. It is noted for comparison that the annually released anthropogenic CO_2 into the atmosphere between 2008 and 2017 is roughly estimated to be 9.5 Pg/yr.

Early observations in the Southern Ocean were rather short to capture the interannual variability of prevailing weather conditions. Sutton et al. (2021) utilized a new approach, making direct measurements of air-sea CO_2, wind speed, and surface ocean properties on an Uncrewed Surface Vehicle (USV). They found that different wind speed products and sampling frequencies have the largest impact on CO_2 flux estimates. Interannual variability could account for discrepancies between different approaches to estimating Southern Ocean CO_2 uptake. Their results indicate that the strong wintertime outgassing observed by floats in 2015 and 2016 was not prevalent in 2019. Therefore, more sustained observations are needed to constrain interannual variability and the impact on both the Southern Ocean and global ocean CO_2 uptake estimates (Sutton et al. 2021).

Despite the paramount importance of the Southern Ocean to the global and marine biogeochemical cycles and advances in observational and analytical techniques, the region was until recently poorly sampled for the CO_2 system and biogeochemical parameters. A typical example of emerging understanding in the last decades is Polynyas, areas of open water surrounded by sea ice. Polynyas play a key role in sea ice and deep-water formation. This rapid ice production in coastal polynyas is linked with water formation of extremely high salinity and density, which is the main source of Antarctic Bottom Water, the deepest layer of the global oceans. Results from new observations show that the open surface waters continue to support high levels of biological productivity and sustain a sink for atmospheric CO_2 in the summertime (Arroyo, 2020).

Outgassing of the Southern Ocean is also indicated from the modern variability of $\Delta^{14}CO_2$, reconstructed by Corran (2021) through annual-resolution tree ring records and atmospheric $\Delta^{14}CO_2$ measurements. Over the short bomb period from the 1950s to 1960s the bomb-pulse shape of the tree ring records corresponds with that of atmospheric measurements. The overall downward trend after the bomb-spike has been dominated by increasing fossil fuel ^{14}C-free CO_2 emissions. The results of the tree ring measurements and harmonized Southern Hemisphere atmospheric CO2 dataset are consistent with one another and show a latitudinal gradient of lower $\Delta^{14}CO_2$ over the Southern Ocean which is associated with deep water upwelling which brings carbon-rich, ^{14}C-depleted water to the surface ocean.

Keppler (2020) studied observational data on the Southern Ocean carbon flux and compiled the temporal mean from 1982 through 2016 shown in Figure 16. The interannual variability of Southern Ocean carbon flux was particularly underlined, exemplified by a stagnation of the Southern Ocean carbon sink in the 1990s, a reinvigoration in the early 2000s, and new weakening again since 2011. It was also demonstrated that substantial variations in the Southern Ocean Carbon cycle are detected in the interior oceanic basin and that the marine carbon sink is subject to considerable decadal variability. Two significant features in this region are stressed by Keppler, the Antarctic Circumpolar Current (ACC), and the consideration that the Southern Ocean is the only basin that has turned from a net carbon source in pre-industrial times, to a net carbon sink at present.

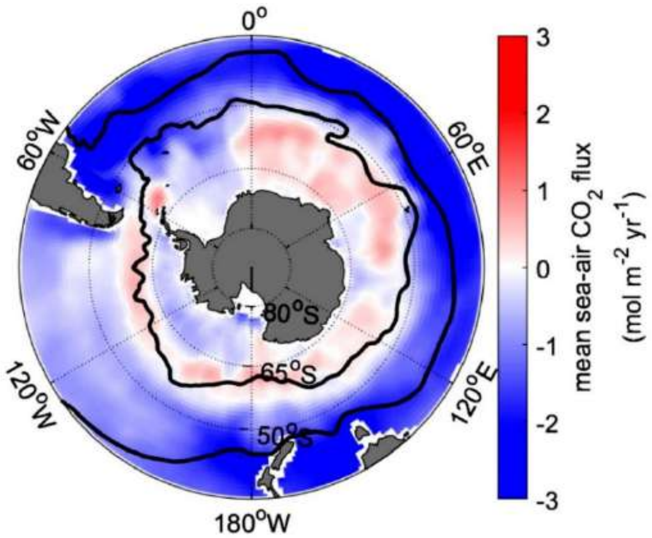

Figure 16: Temporal mean Southern Ocean carbon flux from 1982 through 2016 (blue: oceanic carbon uptake; red: outgassing). The Polar Front (~55ºS) and the Subtropical Front (~40ºS) are illustrated as black lines (Keppler 2020).

The seasonal variability of the carbon flux is significant as shown also in Figure 17 for fCO2, the fugacity of CO2 in the surface seawater obtained by correcting the partial pressure pCO2 for non-ideal gas concentration (Scambos and Stammerjohn 2020).

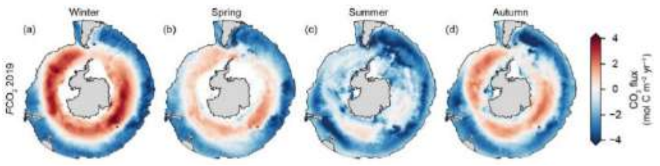

Figure 17. Southern Ocean: seasonal CO_2 fluxes in 2019 (Scambos and Stammerjohn 2020).

3.4 Latest robotic profiling measurements in the Southern Ocean

The interdependence of climate change and the biological carbon pump witnesses the biological aspects of the climate, so far poorly understood. The export of sinking organic particles created by the photosynthetic production of organic matter in the euphotic zone is controlled by the ocean ecosystems. Furthermore, combined upwelling of currents and the biological pump in the Southern Ocean control the amount and stoichiometry of nutrients available for lateral export to lower latitudes, thereby collectively acting as a gatekeeper for the global thermocline nutrient distribution and global ocean productivity. This is a consequence of the unique setting of the Southern Ocean in the global overturning circulation, as it connects the deep ocean below 1,000 m with the ocean's main thermocline through upwelling near the Antarctic Polar Front. The amount of unused nitrate or phosphate available for lateral export from the Southern Ocean to lower latitudes is set by the efficiency of the biological pump (Nissen et al. 2021).

Because of the importance of the biological pump and upwelling in the hostile Southern Ocean and the uncertainties of measurements, novel instrumentation was developed for robotic observations up to a depth of two kilometers and special projects are in progress for the quantification of the carbon cycle and the impacts on the global ocean net primary production. Argo, an international, global observational array of nearly 4,000 autonomous robotic profiling floats and other autonomous platforms has revolutionized the monitoring of physical oceanography. They are considered as the most effective way to globally acquire vertical profiles of key environmental, biogeochemical, and ecosystem variables, amenable to integration with satellite monitoring and the measurements are open in real time (Chai et al. 2020).

The adaptation of robotic floats to extreme conditions provides observational data unimaginable earlier of utmost importance. Thus, to explore the life of phytoplankton during and after the polar night, Randelhoff et al (2020) used robotic ice-avoiding profiling floats to measure vertical profiles of ocean optics and phytoplankton characteristics continuously through two annual cycles in the Baffin Bay, an Arctic Sea that is covered by ice for seven months a year. They demonstrated that net phytoplankton growth occurred even under 100% sea-ice cover as early as February and that it resulted at least partly from photosynthesis. This highlights the adaptation of Arctic phytoplankton to extreme low-light conditions, which may be key to their survival before seeding the spring bloom.

The downward flux of sinking organic particles via the biological pump is reduced by more than 70% in the mesopelagic zone (100 to 1000 meters of depth) and for decades, it has been hypothesized that the missing loss could be explained by the fragmentation of large aggregates into small particles. Similarly, using robotic observations, Briggs et al (2020) quantified the total mesopelagic fragmentation across multiple ocean regions and found that fragmentation accounted for 49 ± 22% of the observed flux loss. Therefore, fragmentation may be the primary process controlling the sequestration of sinking organic carbon.

Quantification of this carbon flux into the oceans, which is critical for the carbon dioxide concentration in the atmosphere, is highly uncertain, ranging from 5 to more than12 Pg/yr of carbon with a range as large as the present annual anthropogenic CO_2 emission rate. Using satellite observations and models Siegel et al. (2014) predicted a climatological mean global carbon export from the euphotic zone of ~6 Pg/yr with an uncertainty of ~20% about this mean value. However, export via sinking particles is one of several pathways through which organic carbon is exported from the surface ocean. For example, the advection of dissolved organic carbon (DOC) with a global estimate of ~2 Pg/yr from the surface ocean is not included. Thus, this global DOC flux combined with the estimate of the sinking carbon export results in a total carbon export of ~8Pg/yr. In addition, a complete assessment of carbon export from the surface ocean must account for this and other additional pathways (Siegel et al. 2014).

As an indication of the quantification uncertainties, it is noted that Stukel and Ducklow (2017), consider that the magnitude of the biological pump in the Southern Ocean is in the range of 1–2 Pg C/yr, a substantial portion of the global biological pump estimates which range from 5 to 13 Pg C/yr. Recent surveys, however, provide much higher levels of the biological pump, both in the Southern Ocean and globally.

Based on year-round biogeochemical measurements with profiling floats, recent work by Chen et al. (2021) has identified a larger than previously estimated release of carbon dioxide from the Southern Ocean to the atmosphere during austral winter. Deep waters exit the Indian, Pacific, and Atlantic Oceans spiral southeastward and upward until reaching the base of the mixed layer in the southern Antarctic Circumpolar Current. This upwelling process is thought to be the major return pathway for remineralized carbon from the ocean's interior to the surface. Observational evidence indicates that there is a substantial transport of old, pre-industrial CO_2 from the deep ocean to the atmosphere through the Southern Ocean surface under present-day conditions.

Notwithstanding that the Southern Ocean plays an enormous role in the global oceanic anthropogenic carbon uptake, CO_2 is also released into the atmosphere across large swaths of the Antarctic Circumpolar Current. Based on data from a novel array of autonomous biogeochemical profiling floats, Prend et al. (2021) estimated that Southern Ocean fluxes of CO_2 transfer carbon predominantly from the Indo-Pacific sector of the Antarctic Circumpolar Current.

Predicting future states of the biological pump is presently considered one of the most challenging and most important scientific challenges of our time. The field campaign is supported by the project EXPORTS (https://oceanexports.org/publications.html) aiming at developing a predictive understanding of the export, fate, and carbon cycle impacts of global ocean net primary production. The sampling array for the EXPORTS Northeast Pacific field deployment was composed of both ship and autonomous sampling platforms; two ships were deployed: a Process Ship and a Survey Ship. The results already shape a new reality for the causes of climate change, given that the biological pump exports roughly 10 Pg C/yr of organic carbon from the surface ocean to depth each year, nearly equivalent to the global fossil fuel emission rate (Siegel et al. 2021).

Integrated over the Southern Ocean south of 30ºS, the model simulates an annual Net Primary Productivity of 17 Pg C/yr which is about 40% higher than the estimates based on satellite chlorophyll observations and various algorithms (~12 Pg C/yr). The model simulates an export of 3.2 Pg C/yr while the estimates derived from observations suggest values between 2.3 and 3.0 Pg C /yr. It is therefore confirmed that the global ocean uptake of 2.5 GtC/yr assumed by Friedlingstein et al. (2019) is seriously underestimated and reveals that global CO_2 outgassing from the ocean is a significant source of CO_2, comparable to fossil fuel burning.

4. Discussion

First, the main points of the proposed model are highlighted, and then the arguments on which our views are based are described. Three climatic periods are distinguished during the Industrial Era. The final phase of the Little Ice Age until 1900, the early industrial period from 1900 to 1960, that is until the Nuclear Testing period, and the Post-Nuclear Era. The short period of Nuclear Testing coincides with the beginning of a steady increase of the mean global temperature and the dramatic rise of the concentration of carbon dioxide in the atmosphere.

It is pointed out that:

in 1957 Ravelle and Suess (1957) concluded that most of the CO_2, released by artificial fuel combustion since the beginning of the industrial revolution must have been absorbed by the oceans,

measurements of CO_2 in the atmosphere and 13C in the CO_2 confirm the abrupt increase of CO_2 since the Nuclear Testing,

the global annual mean temperature increases steadily since the Nuclear Testing,

both CO_2 outgassing and intake have been quantitively confirmed along the Antarctic Circumpolar Current,

recent reliable estimates of global CO_2 intake by the oceans are quantitatively in the range of the CO_2 of the modern fossil fuel burning and because of that an additional significant source of CO_2 is inferred,

it is postulated that the additional carbon is transferred by the oceanic currents from the Pacific, the Indian, and the Atlantic Oceans at the upwelling sites along the ACC

the circulation of the sequestered CO_2 into the currents from deep reservoirs was triggered by the nuclear detonations.

The global temperature increase during the last sixty years is not unprecedented when evaluated in the context of the climate fluctuations during the Medieval Global Anomaly and the Little Ice Age. The current global warming is no doubt a fact but unfortunately misinterpreted so far. It is attributed to the Industrial Era, although a clear change in the trend of global mean temperature evolved only after the nuclear bomb spike in about 1960, as deduced from Figures 1 and 2. It was not monotonous regionally, as already explained, due to the natural erratic variability, seasonal, decadal, or centennial. The temperature measured over a short period for a few decades is not the most consistent indicator of climate change and certainly, projections after fifty or one hundred years are a precarious and misleading task in the current state of insufficient understanding of the climate.

By contrast, the global sudden carbon dioxide rise from ~310 parts per million (ppm) in 1950 to 420 ppm presently is unparalleled in the last 800,000 years and truly shocking and alarming, both for the high level of carbon dioxide concentrations and the outrageous pace of increase of the concentration of the carbon dioxide in the atmosphere. It is close to two ppm per year on average compared to 10 ppm per century in extreme cases of the geological record in the last sixty thousand years. It is exclusively attributed to land-use change and fossil fuel burning, and consequently, this assumption has deterred the research for possible alternative sources, hidden behind the current exponential increase of fossil fuel burning. It happened suddenly without any apparent reorganization of the climate system and because of that, it is most likely anthropogenic in origin. This is witnessed by the sudden change of slope of the carbon dioxide curve which in Figure 4 increases abruptly after about 1960 AD. The abrupt change indicates that a new source of carbon dioxide was added to that from fuel burning.

Paleoclimatic evidence of submillennial-scale variability of carbon dioxide is available for comparison in the ice records of the past sixty thousand years. Two principal modes of CO_2 variability have been identified: (i) millennial-scale carbon dioxide maxima and (ii) centennial-scale carbon dioxide jumps caused by pulse-like CO_2 releases to the atmosphere, during the last deglaciation. The present CO_2 crisis is like the few carbon dioxide jumps identified in the geological past. They have a different pattern since they are superimposed on gradually increasing millennial CO_2 trends and lead to a sudden, 10 to 15 ppm, CO_2 rise within less than ~250 years at rates of ~10 ppm per century (Nehrbass et al. 2020), which is about five times slower than the present extreme rate. In this context, the current climb by 2 ppm annually is not only unprecedented but rather dramatic.

The abrupt character in the rate of carbon dioxide increase is also confirmed from the combined study of greenhouse gases in the twentieth century. The best-substantiated presentation is depicted in Figures 10, in which three periods are noticeable: the pre-industrial before 1850, the early industrial between 1850 and 1960 AD, and the Carbon Dioxide Crisis since the Nuclear Testing.

Figure 8 also is eloquent in the sense that exactly at the bomb-spike in ~1960 the stable isotope ^{13}C in the CO_2 of the atmosphere decreases suddenly and persists so at the new rate, apparently due to sudden and ongoing release at higher than earlier rates of carbon dioxide from a new source, in addition to that from fossil fuel burning.

Similarly, Khatiwala et al. (2009) presented an observationally based reconstruction of the anthropogenic carbon sink in the ocean over the industrial era. Their results indicate that ocean uptake of CO_2 has increased sharply since the 1950s.

Particularly revealing is the study of the West Antarctic climate by Dalaiden et al. (2021) who confirmed strong and widespread continental warming, during the second half of the 20th century since 1958. The West Antarctic climate has witnessed large changes during the second half of the 20th century including strong and widespread continental warming, important regional changes in sea-ice extent and snow accumulation, as well as a major mass loss from the melting of some ice shelves. Major warming has been observed since the International Geophysical Year (i.e., 1958 AD), far exceeding global warming during the same period. They investigated the West Antarctic climate variability over the past two centuries. The climatic reconstruction was based on all the annually resolved snow accumulation and $\delta^{18}O$ records from the Antarctic ice cores, as well as tree-ring proxies, by using a data assimilation approach that combines paleoclimate proxies data and the climate physics from climate models. The overall observed reduction of sea ice extent in the Bellingshausen/Amundsen Sea sector starts at the beginning of the industrial period. In contrast, the increase of sea-ice extent in the Ross Sea sector has started one century later, around 1950 AD, and is preceded by a small sea-ice reduction between 1850 and 1950 AD. It was also shown that the observed general warming since 1958 AD in West Antarctica is not representative of changes over the past 200 years.

5. Conclusions

The trend of carbon isotopes, the CO2, and the global annual mean temperature during the last centuries suggest that climate change started during the Nuclear Testing. Therefore, the association of climate change with the wider Industrial Era is misleading.

The recent observational results indicate that the ocean uptake of CO_2 in the carbon cycle, depicted in Figure 11, is underestimated by four to five times and this confirms that the estimated anthropogenic CO_2 alone cannot explain the measured sharp increase in the atmosphere. On the contrary, a balance should exist between the anthropogenic CO_2 and ocean uptake in the absence of an additional CO_2 source.

Consequently, in addition to the anthropogenic CO2, a significant CO_2 source is active since the Nuclear Testing, which has not been considered so far. Based on recent results of year-round biogeochemical measurements with profiling floats, it is suggested that a larger than previously estimated release of carbon dioxide is recorded in the Southern Ocean. The CO_2 outgassing originates from deep currents in the Indian, Pacific, and Atlantic Oceans which spiral southeastward and upward until reaching the base of the mixed layer in the southern Antarctic Circumpolar Current. This upwelling process is the major return pathway for remineralized carbon from the ocean's interior to the surface.

There is strong and concurring evidence that the carbon dioxide crisis is related not only to the Greenhouse Effect but also to the testing of nuclear bombs at the sites depicted in Figure 18. The detonations disturbed and mobilized sequestered carbon dioxide in deep oceanic layers which through the ocean currents reaches the sea surface at upwelling sites, predominantly in the Southern Ocean.

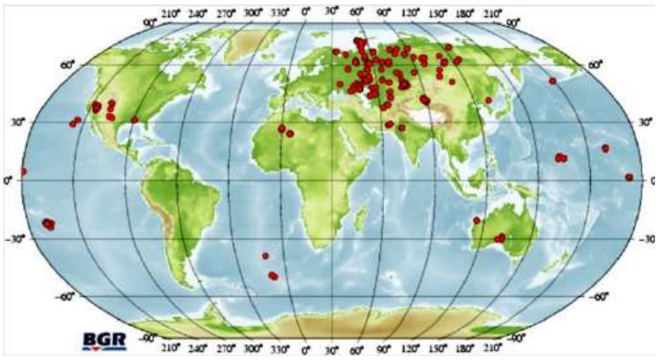

Figure 18. Topographic map of the world with the epicenters of all known nuclear explosions since 1945 (red dots). Source: *BGR (Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) in Hannover.*

Therefore, apart from the Greenhouse Effect, we are confronted with the eventuality of much more severe implications of the Nuclear Testing Effect. It is not argued that the Nuclear Testing Effect is a proven fact, but only that there are recent and strong indications for it and therefore it is an emergency for the scientific community to accelerate their investigations by absolute priority, which requires significant international support and coordination.

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(https://www.researchgate.net/publication/354599622_Nuclear_bomb_tests_as_a_cause_of_climatic_change_a_novel_conceptual_model)

Απλουστευμένη εκδοχή του άρθρου δημοσιεύθηκε στον ιστότοπο in2life στις 5 Οκτωβρίου 2021 με τίτλο «Οι θαλάσσιες πυρηνικές δοκιμές το κύριο αίτιο της κλιματικής αλλαγής - Μια ανησυχητικη ερμηνεία της κλιματικής αλλαγής που σχετίζεται με τις περιβαλλοντικές αμαρτίες του Ψυχρού Πολέμου».
(https://www.in2life.gr/features/notes/article/1011840/oi-thalassies-pyrhnikes-dokimes-to-kyrio-aitio-ths-klimatikhs-allaghs.html)

ΝΕΑ ΑΠΟ ΤΙΣ ΕΛΛΗΝΙΚΕΣ ΚΑΙ ΔΙΕΘΝΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΝΩΣΕΙΣ

International Society for Soil Mechanics and Geotechnical Engineering

ISSMGE News & Information Circular September 2021
https://www.issmge.org/news/news-and-information-circular-september-2021

1. ELECTION OF ISSMGE PRESIDENT 2022-2026

As a consequence of the 20ICSMGE being pushed back to May 2022, and in accordance with the Statutes and Bylaws, the deadline for receiving nominations for the next ISSMGE President has been extended to 30th January 2022.

2. 20ICSMGE / 7iYGEC NEW DATES MAY 2022

New dates have been confirmed for the conferences in Sydney as follows;

7iYGEC - Friday 29 April - Sunday 1 May 2022
20ICSMGE Sunday 1 May Thursday 5 May 2022.

For more information, please visit the conference website (https://icsmge2021.org/) which is in the process of being updated.

3. ISSMGE TC-302 Webinar on "Collapse of Fujinuma Dam by the 2011 Great East Japan Earthquake and its reconstruction" by Prof. Tatsuoka on 18th September, 2021

TC-302 of ISSMGE is conducting a webinar on "Collapse of Fujinuma Dam by the 2011 Great East Japan Earthquake and its reconstruction", by Prof. Fumio Tatsuoka, Professor Emeritus, University of Tokyo and Tokyo University of Science, Japan, on 18th September, 2021 (Saturday), starting at 17:00 hours (Tokyo time)/ 8:00 hours (GMT) /13.30 hours (Indian Standard Time).

Prof. Tatsuoka has pre-recorded his lecture, and requested the TC-302 to circulate the lecture video, along with a few published literature on the topic, to all the members of ISSMGE well in advance. Following is the link to the video file.

https://drive.google.com/file/d/1-GUbD6BrOb_RFo9V0Y9XFY43vCvKLUkj/view?usp=sharing

Also please find below the link to the research papers published by Prof. Tatsuoka on the topic of webinar.

https://drive.google.com/drive/folders/1emfrJ-LFN6Zfvn-MVtXU3loruM5npwDM?usp=sharing

The purpose of sharing the resources before the webinar is to encourage all the interested to send their queries/questions on the lecture, so that Prof. Tatsuoka can effectively respond to all the queries in the Q&A session following the webinar on 18th September, 2021.

Please fill the following registration form for attending the webinar, and you can also submit your questions/queries, if any, after viewing the above video, in the same form.

https://docs.google.com/forms/d/1kTZplR3smGiwb84aqpW0Dmtxkibuq2wXqq4_mvooC_Y/edit?usp=sharing

The meeting link will be shared with all the registered people in due course of time.

4. TIME CAPSULE PROJECT (TCP)

You may already know that an ISSMGE Blog section has been launched as part of the ISSMGE Time Capsule Project (https://www.issmge.org/the-society/time-capsule), the idea being to stimulate personal consideration on the practice of Geotechnical Engineering. Contributions of 200-400 words on any topic that will generate debate within the Geotechnical Engineering profession are encouraged, and may be submitted via the website. For further information, examples of current and upcoming articles, and instructions on submission, please go to the TCP pages on the ISSMGE site https://www.issmge.org/news/tcp-blog-posts

5. NEW WEBINAR

New TC103 Lecture "Numerical Simulations by Energy Piles" by Prof. McCartney, is a new webinar now available from the ISSMGE website.

6. 3rd HUTCHINSON LECTURE - 3rd JTC WORKSHOP NORWAY, 2022 CALL FOR PROPOSALS

The Joint Technical Committee (JTC1) on Natural Slopes and Landslides of the Federation of the International Geo-engineering Societies (FedIGS) is organizing the 3rd JTC1 workshop, which will be held in Norway in Spring, 2022; the provisional title of the event is Landslide initiation, prediction and risk mitigation.

The workshop will host the 3rd Hutchinson Lecture, which has been established by the same JTC1 to award a scholar, aged 42 or less at the time of the event, who has significantly contributed to the development of knowledge in the field of slope stability and landslides. The Hutchinson Lecture should deal with a subject consistent with the workshop issues. The lecture will be published in an international journal.

The Hutchinson lecturer, who should have a disciplinary background from one or more of the domains of the geosciences, will be chosen - by vote of JTC1 Committee members - among candidates proposed by national societies. All countries are then asked to propose their own candidate. The proposals, accompanied by the candidate CV, should be submitted to the JTC1 chairman, Luciano Picarelli, by September 15th 2021 (luciano.picarelli@unicampania.it) .

7. BULLETIN

The latest edition of the ISSMGE Bulletin (Volume 15, Issue 3, August 2021) is available from the website https://www.issmge.org/publications/issmge-bulletin/vol-15-issue-4-august-2021

8. ISSMGE FOUNDATION

The next deadline for receipt of applications for awards from the ISSMGE Foundation is the 30th September 2021. Click here for further information on the ISSMGE Foundation.

9. CONFERENCES

For a listing of all ISSMGE and ISSMGE supported conferences, and full information on all events, including deadlines, please go to the Events page at www.issmge.org/events. However, for updated in-formation concerning possible changes due to the corona-virus outbreak (ie. Postponements, cancellations, change of deadlines, etc), please refer to that specific events website.

As might be expected, many events have been rescheduled and we update the Events page whenever we are advised of changes.

The following are events that have been added since the previous Circular:

ISSMGE Events

6TH INTERNATIONAL CONFERENCE ON GEOTECHNICAL AND GEOPHYSICAL SITE CHARACTERIZATION - 26-09-2021 - 29-09-2021 Budapest Congress Center, Budapest, Hungary; Language: English; Organiser: Hungarian Geotechnical Society; Contact person: Tamás Huszák; Address: Muegyetem rkp. 3.; Email: info@isc6.org; Website: http://isc6.org

GEONIAGARA - CANADIAN GEOTECHNICAL SOCIETY'S ANNUAL CONFERENCE - 26-09-2021 - 29-09-2021 ON Convention Centre, Niagara Falls, Canada; Organiser: Canadian Geotechnical Society; Contact person: Lisa Reny; Address: 2167 166 Street; Phone: 7788342010; Email: lisa@karma-link.ca; Website: https://www.geoniagara2021.ca/; Email: admin@geoniagara2021.ca

SECOND GENERATION OF EUROCODE 7 – IMPROVEMENTS AND CHALLENGES - 28-09-2021 - 29-09-2021 Online, Netherlands; Language: English; Organiser: ISSMGE ERTC10; Contact person: Georgios Katsigiannis (Chair of ISSMGE ERTC10); Email: georgios.katsigiannis@ekfb.com; Website: https://second-generation-of-eurocode7.nen-evenementen.nl/

FUTURE OF GEOTECHNICS - 04-10-2021 - 05-10-2021 Online, United States; Language: English; Organiser: YMPG; Contact person: Lucy Wu; Email: info@futuregeo.org; Website: https://www.futureofgeo.org/

INTERNATIONAL YOUNG PROFESSIONALS WORKSHOP ON RAIL-ROAD INFRASTRUCTURE - 26-11-2021 - 27-11-2021 Hybrid, Sydney, Australia; Language: English; Organiser: Transport Research Centre, University of Technology Sydney; Contact person: Christine Smith; Email: christine.smith-1@uts.edu.au; Website: https://www.uts.edu.au/research/transport-research-centre

17TH DANUBE - EUROPEAN CONFERENCE ON GEOTECHNICAL ENGINEERING - 07-06-2023 - 09-06-2023 Ramada Parc, Bucharest, Romania- September 2023); Language: English; Organiser: Romanian Society for Geotechnical and Foundation Engineering; Contact person: Alexandra Ene; Address: Bvd. Lacul Tei 124; Email: srgf@utcb.ro; Website: http://www.17decge.ro

NON-ISSMGE Events

BUCHANAN LECTURE - 12-11-2021 Online, United States, College Station; Language: English; Organiser: Jean-Louis Briaud; Contact person: Blake Thurman; Address: 3135 TAMU; Phone: 9794581024; Email: blake960@tamu.edu; Website: https://briaud.engr.tamu.edu/buchananlecture/

International Young Professionals Workshop on Rail-road Infrastructure (YPWRI) 26th November 2021

International Young Professionals Workshop on Rail-road Infrastructure (YPWRI) will be held in hybrid (combining a physical event in Sydney, Australia with an online option) on 26 November 2021.

The workshop receives unreserved support from the ARC Training Centre for Advanced Technologies in Rail Track (ITTC-Rail), the Australian Geomechanics Society (AGS) and the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) through TC 202: Transportation Geotechnics.

This full-day workshop will provide young professional engineers and research students useful exposure to current and future industry trends, national priorities and current developments in transport infrastructure, and to learn and share their knowledge and experience through networking with peers. The wide array of presentations will focus on R&D outcomes of significant industry impact, state-of-practice in national and international mega projects as well as technological innovations which will be of interest to a broad audience.

Click here to see more details.

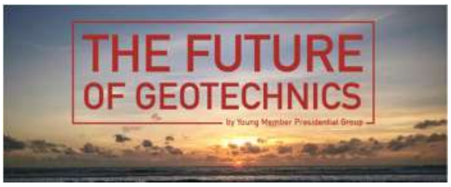
2nd International Workshop on Numerical Methods for Large Deformation Problems in Geotechnical Engineering (Tongji University)

Dear colleague,

The 2nd International Workshop on Numerical Methods for Large Deformation Problems in Geotechnical Engineering (INLGEO) will be held at Tongji University on18th and 19th September 2021 (online for international participants). The workshop focuses on (not limited to) the frontiers of various large deformation numerical methods, the application of large deformation numerical methods in the risk analysis of geotechnical and underground engineering, and the challenges of large deformation numerical methods in simulating water-soil-structure interaction.

We sincerely invite you to attend this workshop to share cutting-edge international issues and the latest research results. This workshop is an invited meeting, and no registration fee is charged. If you plan to attend, please **register on the webpage** of the conference (https://www.eventbrite.com/e/2nd-inlge-registration-169245282195). After registration, the link of workshop live broadcast stream will be sent to your email in time.

Future of Geotechnics



The YMPG invites all geo-professionals to the Future of Geotechnics, a series of online events to explore the future of our profession. We will explore the intersection of the mitigation of climate change, adaptation to climate change, technology, AI, and big data in geotechnics. Come get involved in some of the most important questions and challenges our society will face in the next 40 years.

See you there and reshare to your networks!

Register Now for the Future of Geotechnics!

These sessions are meant to be inspirational, not educational. This is a chance to broaden your horizons about challenges our world will face and how the geotechnical profession can be a part of engineering the solution for tomorrow. We hope you will continue the conversation in your professional communities.

ISRM International Society for Rock Mechanics and Rock Engineering

New ISRM website launched in August

As you have already noticed, the ISRM has launched a new website, to be found at the same address www.isrm.net. It has a new graphical design responsible for mobile phones and tablets, new functionalities and easier access to content. This is one more step for the modernization of our Society, one of the Board's objectives. The ISRM hopes that you enjoy our new website.

35th ISRM Online Lecture

For the 35th ISRM Online Lecture, the ISRM invited Dr Christine Detournay, Principal Engineer at Itasca Consulting Group. The title of the lecture is "Findings from Numerical Modeling at the Site of a High Dam on the Jinsha River ". It was broadcasted on the 16th September 2021 at www.isrm.net.

Christine Detournay started working as a consultant for Itasca in 1986, where she is now a Principal Engineer. She holds a Geoengineering degree from the University of Liege, Belgium and a MSc and PhD degrees in Civil Engineering from the University of Minnesota. Her expertise is in the development of numerical models for application to coupled fluid-thermo-mechanical problems. She has contributed in the development of several Itasca codes, including FLAC, FLAC3D, 3DEC, and XSite. She is a principal developer for the groundwater-flow and thermal logic in FLAC3D and has been involved in the implementation of several of the constitutive models available with Itasca continuum codes. She has worked in consulting and development for various projects related to the oil and gas industry, including hydraulic fracturing, as well as on projects pertaining to underground waste repository, geothermal applications, slope stability, soil liquefaction and CO2 sequestration. She has co-authored more than 65 publications, including conference papers, journal papers, and book chapters.

The lecture will remain online so that those unable to attend at this time will be able to do it later. As usual, the attendees will be able to ask questions to the lecturer by e-mail during the subsequent five days. All online lectures are available from this page.

News
https://www.isrm.net

50 years Commemorative Session of the Journal GEOTECNIA, 20-21 September, Lisbon, Portugal 11 Sep, 2021
The Portuguese Geotechnical Society (SPG) celebrates the 50th anniversary of GEOTECNIA Journal (together with the Brazilian and Spanish geotechnical associations - ABMS and SEMSIG), with an event that will take place on 20 and 21 September 2021, in person, at the Portuguese National Laboratory for Civil Engineering - LNEC, in Lisbon, PORTUGAL, with simultaneous live broadcasting. Participation is free of charge but subject to prior compulsory registration (https://forms.gle/GcPQFYgmM8PreVEY6).

The 35th Online Lecture is online 16 Sep, 2021
35th Online Lecture "Findings from Numerical Modeling at the Site of a High Dam on the Jinsha River" by Dr. Christine Detournay, Principal Engineer at the Itasca Consulting Group

The ISRM Young Members' Monthly Webinar Series is on its way 20 Sep, 2021
The program will create a global network for ISRM young members to connects and share knowledge, experiences, and ideas. Young rock mechanics professionals and enthusiasts working for industry, government agencies, research and development, or academia, regardless of their sector and their location in the world are invited to join the talks or consider giving a talk.

Webinar on "Second Generation of Eurocode 7 - Improvements and Challenges", 28 September 2021, 15:00-17:00 CEST 22 Sep, 2021
We received from CEN (the European Committee for Standardization) the announcement of the "Second Generation of Eurocode 7 - Improvements and Challenges", which will take place on 28 September 2021, 15:00-17:00 CEST.

2021 ISRM Latin American Lecture Tour: 27 September - 1 October 22 Sep, 2021
The main objective of the "Lecture Tour" is to invite some known specialists from abroad, selected among ISRM members, to give lectures in areas of interest in rock mechanics and rock engineering for National Groups in Latin America.

Eurock2021: ISRM Awards Ceremony and Closing Session is open to all, 24 September, 14:40 CEST 23 Sep, 2021
Both sessions are open to the public

The Autum 2021 ISRM newsletter is online 30 Sep, 2021
The Autum 2020 Newsletter with the latest news and future events was sent to all members and is available on the site

Scooped by ITA-AITES #51, 14 September 2021

China-made tunnel boring machine, the world's largest, put into use in Georgia

Gary Taylor: Auckland needs a proper metro rail system | New Zealand

Construction of Loyang MRT station on Cross Island Line to start in Q4 | Singapore

More excavation works on Davao City Bypass Road's twin tunnels under way | Philippines

Single bidder shortlisted for Gozo tunnel project | Malta

Modi govt proposes 15.6-km twin road tunnel of strategic importance under Brahmaputra | India

Look back at HS2 milestones hit during first year of construction | UK

First look at Metrolinx's tunnel boring machine used on Scarborough subway extension | Canada

Sydney's new harbour road tunnel at risk of delay after contract U-turn | Australia

Silvertown Tunnel contractors prepare for tunnelling with enabling works well advanced | UK

Scooped by ITA-AITES #53, 28 September 2021

Ontario reaches next stage of the Scarborough Subway Extension | Canada

Al-Sisi inaugurates Ahmed Hamdi Tunnel II, several development projects in Sinai | Egypt

London Underground's Northern line extension comes into service | UK

Gary Taylor: Auckland needs a proper metro rail system | New Zealand

Metro's preferred expansion option would create second Potomac River tunnel, add Georgetown station | United States of America

Swiss underground goods conveyance network gets go ahead

Namma Metro: Tunnel boring machine emerges at Shivajinagar | India

Western Sydney Airport metro secures final planning approval | Australia

Hengqin LRT line extension underwater tunnel completed in 2022 | Macau, China

Construction of new metro station kicks off in Baku | Azerbaijan

British Tunnelling Society Young Members

The design of gaskets for segmentally lined tunnels

Lecture broadcasted live on YouTube
Thursday 9th September 2021 at 18:00 hrs [UTC+1]
Online at : https://youtu.be/oOb43g4Oe9c

Speaker

Mike King – Director, MK Tunnelling Limited

Waterproofing gaskets for segmentally lined tunnels form a critical element within the tunnelling system.

Poor design or selection choices can cause problems not only for the environment, the tunnel internal fixtures and fittings, and levels of comfort during construction and operation, but to the durability of the lining itself, operational safety, and even instability of the lining through the gradual loss of essential ground support. However, with just a little care they offer a cheap solution to a range of potential issues.

Mike's presentation considered aspects of material choice and material characteristics for the gasket as well as design and testing approaches and influencing factors for both well-established and new profiles.

☙ ❧

International Association for Engineering Geology and the Environment

IAEG Connector E-News

Professor Paul Marinos to receive Honorary President of IAEG Award in Athens

Emeritus Professor of Engineering Geology at the National Technical University of Athens, Paul Marinos, will receive the "Honorary President of IAEG Award" in Athens at our meeting next week. It will first have to be ratified by the AEG Council. It has been voted on with a unanimous vote by the IAEG Executive Committee. Professor Marinos has had an incredible career. He has been President of the Geological Society of Greece and also IAEG from 1994-1998. He has also won the Hans Cloos Medal from IAEG. Congratulations to Professor Marinos! To read more about his illustrious career, use the link below.

READ MORE

Newsletter of
Environmental, Disaster, and Crises Management Strategies
Post Graduate Program
Environmental, Disaster, and Crises Management Strategies

Newsletter #25 - The July - August 2021 Wildfires in Greece

Δημοσιεύτηκε το **25ο τεύχος** του **"Newsletter of Environmental, Disaster, and Crises Management Strategies**", που εκδίδεται υπό την αιγίδα του Προγράμματος Μεταπτυχιακών Σπουδών "**Στρατηγικές Διαχείρισης Περιβάλλοντος, Καταστροφών και Κρίσεων**" του **Εθνικού και Καποδιστριακού Πανεπιστημίου Αθηνών** παρουσιάζοντας τα πρώτα επιστημονικά δεδομένα και συμπεράσματα που προέκυψαν από τις σημαντικότερες καταστροφικές πυρκαγιές που έπληξαν τον ελλαδικό χώρο κατά την περίοδο Ιουλίου και Αυγούστου 2021.

Το τεύχος με τίτλο "**The July - August 2021 Wildfires in Greece**" είναι αποτέλεσμα γόνιμης συνεργασίας και ανταλλαγής γνώσεων μεταξύ επιστημόνων από τα Τμήματα **Γεωλογίας** (Τομείς Δυναμικής, Τεκτονικής & Εφαρμοσμένης Γεωλογίας και Γεωγραφίας & Κλιματολογίας) **Βιολογίας**, **Φυσικής** και **Μικροβιολογίας** του ΕΚΠΑ, το **Τμήμα Γεωγραφίας του Χαροκόπειου Πανεπιστημίου Αθηνών**, του **Δήμου Ρόδου** και του **Πυροσβεστικού Σώματος**.

Περιλαμβάνει:

- τα αποτελέσματα πρόσφατης μελέτης που εξηγεί γιατί η περιοχή της Μεσογείου αποτελεί ένα κλιματικό hot spot για δασικές πυρκαγιές,
- τα μέσα πυρόσβεσης της Ελλάδας και τα στατιστικά στοιχεία για τις πυρκαγιές των δασών τα τελευταία 20 χρόνια στην Ελλάδα,
- τις ενέργειες απόκρισης που περιλαμβάνουν μηνύματα προειδοποίησης από τον ευρωπαϊκό αριθμό τηλεφώνου έκτακτης ανάγκης 112 και την ενεργοποίηση του μηχανισμού πολιτικής προστασίας της ΕΕ,
- τη χαρτογράφηση των πυρόπληκτων περιοχών και της σφοδρότητας της πυρκαγιάς με τη χρήση εικόνων ESA Copernicus Sentinel-2 και δορυφορικές εικόνες υψηλής ανάλυσης (PlanetScope),
- την καθημερινή εξέλιξη των πυρκαγιών,
- τις χρήσεις γης και τις γεωλογικές και γεωμορφολογικές ιδιότητες των πυρόπληκτων περιοχών,
- τις επιπτώσεις των πυρκαγιών:

  α) στους ανθρώπους, συμπεριλαμβανομένων των επιπτώσεων στη δημόσια υγεία και την εκκένωση κατοικημένων περιοχών

  β) στη βλάστηση και την πανίδα

  γ) στις ιδιοκτησίες που περιλαμβάνουν κτίρια, καλλιέργειες, φυτείες κλπ,

  δ) στις υποδομές που περιλαμβάνουν επικοινωνίες, δίκτυα ηλεκτρικής ενέργειας και ύδρευσης και στοιχεία του συστήματος πυροπροστασίας (δεξαμενές)

  ε) σε οχήματα διαφόρων τύπων

  με βάση επιτόπιες έρευνες κατά τη διάρκεια και μετά από την πυρκαγιά στις περιοχές που έχουν πληγεί
- την ατμοσφαιρική ρύπανση που παρατηρείται στις πληγείσες περιοχές από πυρκαγιά,
- τις σύνθετες καθημερινές ανωμαλίες της θερμοκρασίας του επιφανειακού αέρα σε περιοχές που έχουν πληγεί από πυρκαγιά,
- τις ενέργειες αντιμετώπισης έκτακτης ανάγκης για την οικονομική υποστήριξη του πληθυσμού που έχει πληγεί,
- τον αντίκτυπο των πυρκαγιών στην ψυχική υγεία κατά τη διάρκεια της απόκρισης στην κατάσταση έκτακτης ανάγκης και της φάσης αποκατάστασης που περιλαμβάνει ατομικές αντιδράσεις, πιθανά και κοινά συμπτώματα καθώς και πρώιμες στρατηγικές ψυχοκοινωνικής υποστήριξης,
- τον αντίκτυπο των πυρκαγιών στη δημόσια υγεία κατά τη διάρκεια της αντιμετώπισης της κατάστασης έκτακτης ανάγκης και της φάσης αποκατάστασης που αναφέρεται στις χημικές ουσίες που βρίσκονται στον καπνό της πυρκαγιάς, στην έκθεση σε σωματίδια, στις κλινικές και υποκλινικές επιπτώσεις του καπνού πυρκαγιάς, στην έκθεση μέσω εισπνοής, στις διαφορές μεταξύ των συμπτωμάτων από την έκθεση στον καπνό και του COVID-19, σε συγκεκριμένες στρατηγικές για τη μείωση της έκθεσης στον καπνό πυρκαγιάς, στην αναπνευστική προστασία για τον καπνό και τη στάχτη από πυρκαγιές και
- τους πιθανούς μεταπυρικούς κινδύνους, συμπεριλαμβανομένης της διάβρωσης, των κατολισθήσεων και των πλημμυρών, που δημιουργούν μια επιτακτική ανάγκη για άμεση πολυπαραμετρική και διεπιστημονική έρευνα.

Το 25ο τεύχος του Newsletter of Environmental, Disaster, and Crisis Management Strategies έρχεται για πρώτη φορά σε μια πρόσθετη, **πλήρως on-line έκδοση**.

Εκτός από την ηλεκτρονική έκδοση pdf του Newsletter, η καινοτόμος αυτή προσέγγιση χρησιμοποιεί την πλατφόρμα ESRI ArcGIS Hub, η οποία ενσωματώνει όλα τα πλεονεκτήματα της σύγχρονης ψηφιακής τεχνολογίας και των Γεωγραφικών Συστημάτων Πληροφοριών. Το τελικό προϊόν είναι διαδραστικό, εύκολα προσβάσιμο και ανανεώσιμο. Χρησιμοποιώντας έξυπνες διατάξεις, πρότυπα και εργαλεία, η πλατφόρμα περιλαμβάνει διαδραστικούς χάρτες και περιεχόμενο πολυμέσων που μπορούν να διαμορφωθούν ώστε να προβάλλουν καλύτερα τις διαθέσιμες πληροφορίες.

Σχεδόν όλο το περιεχόμενο αυτού του τεύχους είναι διαθέσιμο σε ειδικά αφιερωμένο Hub, εμπλουτισμένο με διαδραστικούς χάρτες χρονοσειράς, βίντεο, εικόνες πριν και μετά κ.ά.

Το τεύχος είναι διαθέσιμο **εδώ**, ενώ η ψηφιακή του αποτύπωση (Hub) είναι προσβάσιμη **εδώ**.

ΠΡΟΣΕΧΕΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΚΔΗΛΩΣΕΙΣ

Για τις παλαιότερες καταχωρήσεις περισσότερες πληροφορίες μπορούν να αναζητηθούν στα προηγούμενα τεύχη του «περιοδικού» και στις παρατιθέμενες ιστοσελίδες.

THE FUTURE OF GEOTECHNICS

by Young Member Presidential Group

4-5 October 2021
www.futureofgeo.org

Be inspired to think beyond your own borders.

Join us for a series of presentations and discussions on the future of our profession.

What will the World look like in 40 years?

Join us for a conversation on the future of geotechnical engineering.

These sessions are meant to be inspirational, not educational. This is a chance to broaden your horizons about challenges our world will face and how the geotechnical profession can be a part of engineering the solution for tomorrow. We hope you will continue the conversation in your professional communities.

Technology, AI, Big Data

Artificial Intelligence
Big Data
Remote sensing
Machine learning

The intersection of technology and geotechnical engineering View Event →

Adaptation to Climate Change

Extreme GeoHazard Events
Coastal Erosion
Resiliency
Sea Level Rise

Designing and building our world to respond to the effects of climate change, sea level rise, coastal erosion, increased frequency of natural disasters View Event →

Mitigation of Climate Change

Energy Geotechnics
CO_2 Storage
Renewable Energy
Circular Carbon Economy

Mitigating carbon emissions through circular carbon economy, renewable energy, energy geotechnics, and carbon sequestration View Event →

Resources

Increase your technical knowledge with these online resources, papers, and events

Responding to Climate Change Through Geotechnical Engineering Research

Online webinar from the National Academy of Sciences that gives an overview of climate challenges and geotechnical engineering research

Digitisation, Sustainability, and Disruption – Promoting a More Balanced Debate on Risk in the Geotechnical Community

A paper that challenges engineers to step back from their technical work and take a broader view of the world

ICSMGE 2022

The 20th International Conference on Soil Mechanics and Geotechnical Engineering 2022

Virtual University

ISSMGE's open access educational platform. More courses added everyday!

YMPG

Young Member Presidential Group

A Board Level Committee of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE)

☙ ❧

14th Basements and Underground Structures Conference / 10th biennial Instrumentation and Monitoring Conference, 6 October 2021, London, United Kingdom, https://basements.geplus.co.uk, https://monitoring.geplus.co.uk

EUROENGEO 3RD EUROPEAN REGIONAL CONFERENCE OF IAEG, 7 - 10 October 2021, Athens, Greece, www.euroengeo2020.org

☙ ❧

SARDINIA2021

18th International Symposium on Waste Management and Sustainable Landfilling
11-15 October 2021, Cagliari, Italy
www.sardiniasymposium.it

The Sardinia Symposia are a biennial event organized by the **International Waste Working Group (IWWG)**, with the scientific support of the Universities of Padova, Tongji, Fukuoka and the Technical Universities of Luleå and Hamburg.

Founded in 1987, the conference usually gathers more than 700 participants from all around the world, with more than 400 papers presented at each edition, making the Sardinia Symposium the most important solid waste management conference in the world.

Sessions

- Environmental issues
- Sanitary landfilling
- Biological treatment
- Thermal treatment
- Characterisation, minimisation & recycling
- WM in DC's
- Non technical issues
- Special & industrial waste
- Active lab

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url: www.eurowaste.it

TC-Hydraulics Workshop (Hybrid Event):
"Geosynthetics for drainage and filtration in barrier systems"

The IGS Technical Committee on Hydraulics hosts a workshop on 14 October from 15:00 - 18:00 CEST at the next *Sardinia Symposium*, a hybrid event. The workshop, chaired by IGS Past President Daniele Cazzuffi (Italy), will include presentations covering state-of-the-art applications of drainage geosynthetics in landfill barrier systems.

Part One will feature lectures by Eric Blond (Canada), Pietro Rimoldi (Italy), Piergiorgio Recalcati (Italy), Maria Clorinda Mandaglio (Italy) and Adam Maskal (USA).

An hour-long panel discussion will follow in Part Two, where speakers will take questions from the audience to encourage an in-depth, expert discussion on this topic.

Join this informative and innovative event today!

WORKSHOP PROGRAM - ENTRANCE FEES - REGISTER

10th International Conference on Scour and Erosion (ICSE-10), October 17-20, 2021, Arlington, Virginia, USA, www.engr.psu.edu/xiao/ICSE-10 Call for abstract.pdf

3rd International Symposium on Coupled Phenomena in Environmental Geotechnics, 20-22 October 2021, Kyoto, Japan, https://cpeg2020.org

ARMS11 11th Asian Rock Mechanics Symposium, Challenges and Opportunities in Rock Mechanics, 21-25 October 2021, Beijing, China, www.arms11.com

HYDRO 2021 Roles of hydro in the global recovery, 25-27 October 2021, Strasbourg, France, www.hydropower-dams.com/hydro-2021

EURO:TUN 2021 Computational Methods and Information Models in Tunneling, October 27th - 29th, 2021, Bochum, Germany, http://eurotun2021.rub.de

GFAC 2021 International Conference "Geotechnics fundamentals and applications in construction: investigations, design, technologies", October 27–29, 2021, Saint Petersburg, Russia https://gfac.spbgasu.ru

Emerging Technologies and Applications for Green Infrastructure, 28-29 October 2021, Ha Long, Vietnam, https://cigos2021.sciencesconf.org

5TH World Landslide Forum Implementation and Monitoring the USDR-ICL Sendai Partnerships 2015-2025, 2-6 November 2021, Kyoto, Japan, http://wlf5.iplhq.org

ASIAFUGE 2021 - Tackling Modern Geotechnical Complexity with Physical Modelling, 18th & 19th November 2021, Singapore, www.asiafuge-sg.com

ICGE – Colombo – 2020 3rd International Conference in Geotechnical Engineering, 6-7 December 2021, Colombo, Sri Lanka, http://icgecolombo.org/2020/index.php

2nd International Conference TMM-CH Transdisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultural Heritage - Rebranding The World In Crisis Through Culture, 12-15 December, 2021 Athens, Greece https://tmm-ch.com/

GeoAfrica 2021 - 4th African Regional Conference on Geosynthetics Geosynthetics in Sustainable Infrastructures and Mega Projects, 21-24 February 2022, Cairo, Egypt, https://geoafrica2021.org

16th ICGE 2022 – 16th International Conference on Geotehnical Engineering, Lahore, Pakistan, 23-24 February, 2022, https://16icge.uet.edu.pk/

15 - 17 March 2022, Kuala Lumpur, Malaysia
www.hydropower-dams.com/asia-2022

THE SECOND BETANCOURT CONFERENCE "NON-LINEAR SOIL-STRUCTURE INTERACTION CALCULATIONS"
April 2022

Augustin Betancourt was an outstanding offspring of the Spanish nation and a citizen of the Russian empire, the founder of the Russian engineering school, the first head of a Russian agency for architecture and civil engineering. Betancourt Conferences are devoted to discussion of the important engineering problems faced by the professional community. The conference characteristic feature is involvement of experts of various profiles in discussion of relevant issues that fosters interdisciplinary communication and synthesis of knowledge.

The first conference held in June 2019 was devoted to underground urban planning, it drew attention of city planners, architects, geotechnical engineers, historical city preservation activists. Expectedly, the discussion of issues of underground space development resulted in creation of the regulatory document – Set of Rules 473.1325800.2019 "Buildings, structures and underground complexes. The rules of city planning design".

At the Second Betancourt Conference, which is going to be held in April in the format of video conference, we suggest to discuss burning issues of soil-structure interaction calculations taking into account non-linear and rheological properties of soils and structures which solution is impossible without a synthesis of engineering knowledge in the field of geotechnical engineering and design of superstructures.

For the Organizing Committee of the Conference

Professor Vladimir Ulitsky
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16th International Benchmark Workshop on Numerical Analysis of Dams, 6–8 April 2022, Ljubljana, Slovenia, https://icold-bw2022.fgg.uni-lj.si

ICEGT-2020 2nd International Conference on Energy Geotechnics, 10-13 April 2022, La Jolla, California, USA, https://icegt-2020.eng.ucsd.edu/home

2022 GEOASIA7 - 7th Asian Regional Conference on International Geosynthetics Society, April 11 - 15, 2022, Taipei, Taiwan, www.geoasia7.org

WTC 2022 World Tunnel Congress 2022 - Underground solutions for a world in change, 22-28 April 2022, Copenhagen, Denmark, www.wtc2021.dk

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RaSiM10
Rockbursts and Seismicity in Mines

Rockbursts and Seismicity in Mines
24 – 29 April 2022, Tucson, USA
www.rasimsymposium.com

Explore Innovations in Rockbursts & Seismicity in Mines

RaSiM10 provides a forum to share state-of-the-art scientific advances, to introduce technical innovations, to discuss the state-of-practice engineering and mine operations in seismically active mines experiencing rockbursts.

Interact with industry experts sharing the latest in technology, innovations and safety at RaSiM10: Rockbursts and Seismicity in Mines Conference. This global mining event focuses on topics surrounding this vital aspect of mining, including:

- Seismic Monitoring and Data Analysis
  - Seismic Monitoring hardware and software
  - Seismic Data Processing and Interpretation
  - Operational Seismic Management in Mining
  - Spatial/Temporal Seismic Analysis
- Mechanistic Analysis
  - Strainburst mechanics
  - Fault slip mechanics
  - Dynamic modelling
  - Back analysis and modelling
- Risk Assessment and Mitigation
  - Advances in Rockburst Seismology
  - Spatial Seismic Risk Recognition
  - Advances in Seismic Risk Mitigation
  - Engineering Geology and Seismic Hazard
- Management and Control
  - Advances in Rockburst Seismology
  - Spatial Seismic Risk Recognition
  - Advances in Seismic Risk Mitigation
  - Engineering Geology and Seismic Hazard
- Comprehensive Industry Case Studies

Organized in partnership by the Society for Mining, Metallurgy & Exploration, the University of Arizona, and Queens University this features a tailored, high-end technical sessions focusing on innovation and practical knowledge, this dynamic event connects industry professionals leading the way in technology and process development.

Contact Us

Conference Organizer & General Information

SME
12999 E. Adam Aircraft Circle
Englewood, CO 80112
Tel: 720.738.4085 or 1.800.958.1550 (US Only)
Email: **cs@smenet.org**

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SYDNEY 7iYGEC 2021 7th International Young Geotechnical Engineers Conference A Geotechnical Discovery Down Under, 29 April - 1 May 2022, Sydney, Australia, http://icsmge2021.org/7iygec

SYDNEY ICSMGE 2021 20th International Conference on Soil Mechanics and Geotechnical Engineering, 1–5 May 2022, Sydney, Australia, www.icsgme2021.org

LARMS 2021 – IX Latin American Rock Mechanics Symposium Challenges in rock mechanics: towards a sustainable development of infrastructure, 15 – 18 May 2022, Asuncion, Paraguay, https://larms2021.com

2022 ICOLD 27th Congress - 90th Annual Meeting 27 May - 3 June 2022, Marseille, France, https://cigb-icold2022.fr/en

CPT'22 5th International Symposium on Cone Penetration Testing, 8-10 June 2022, Bologna, Italy, http://cpt22.org

3rd European Conference on Earthquake Engineering and Seismology (3ECEES), 19-24 June 2022, Bucharest, Romania, https://3ecees.ro

3rd International Symposium on Geotechnical Engineering for the Preservation of Monuments and Historic Sites 22-24 June 2022, Napoli, Italy, https://tc301-napoli.org

9th International Congress on Environmental Geotechnics
Highlighting the role of Environmental Geotechnics in Addressing Global Grand Challenges
26-29 June 2022, Chania, Crete island, Greece
www.iceg2022.org

The 9th International Congress on Environmental Geotechnics is part of the well established series of ICEG. This conference will be held on an outstanding resort in the town of Chania of the island of Crete in Greece. The theme of the conference is "Highlighting the role of Environmental Geotechnics in Addressing Global Grand Challenges" and will highlight the leadership role of Geoenvironmental Engineers play on tackling our society's grand challenges.

Contact Information

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IS-Cambridge 2020 10th International Symposium on Geotechnical Aspects of Underground Construction in Soft Ground, 27 - 29 June 2022, Cambridge, United Kingdom, www.is-cambridge2020.eng.cam.ac.uk

5.ICNDSMGE – ZM 2020 5th International Conference on New Developments in Soil Mechanics and Geotechnical Engineering, June 30 to July 2, 2022, Nicosia, Cyprus, https://zm2020.neu.edu.tr

UNSAT2022
8th International Conference on Unsaturated Soils
June or September 2022, Milos island, Greece

ICONHIC2022: THE STEP FORWARD - 3rd International Conference on Natural Hazards & Infrastructure, 5 – 7 July 2022, Athens, GREECE, https://iconhic.com/2021

4th International Conference on Rock Dynamics
an ISRM Specialized Conference
17-19 August 2022 in Xuzhou, China
http://rocdyn.org

The Fourth International Conference on Rock Dynamics and Applications (**RocDyn-4**) will be held on 17-19 August 2022 in Xuzhou, China. This follows the successful series of RocDyn conferences since 2013 (RocDyn-1 in Switzerland, RocDyn-2 in China, RocDyn-3 in Norway) .

RocDyn-4 is a Specialized Conference under the International Society for Rock Mechanics and Rock Engineering (ISRM). The main theme is "Rock Dynamics: Progress and Prospect", with the aim to take stock of the significant progress that rock dynamics has made since the formation of the ISRM Commission on Rock Dynamics in 2008 and the RocDyn-1 conference in 2013, examine new research areas and applications, and look to the future of rock dynamics.

Rock dynamics has wide applications in defense, civil engineering and infrastructure, energy and mining, and geo-hazards and the environment. It covers a wide scope of topics on the behavior of rock materials and rock mass under dynamic loads, ranging from characterization and the propagation of stress waves in geological media to dynamic response of rock and rock structures and dynamic rock support.

We invite all those involved in rock dynamic research and engineering to submit papers and join us in Xuzhou in 2022, to share, to exchange, to cooperate and to renew our friendship.

Due to the impact and limitations of COVID-19 pandemic, **RocDyn-4 will adopt a hybrid on-site and virtual attendance format**.

Main Theme

The main theme for RocDyn-4 is "**Rock Dynamics: Progress and Prospect**".

Topics

The technical programme will cover all the aspects related to rock dynamics and engineering applications, including, but not limited to the following topics:

- Theory and experimental techniques
- Dynamic properties of rock material and rock mass
- Multi-scale and multi-physics
- Analytical and numerical methods.
- Sources and characterization of dynamic load
- Wave propagation in geological media
- Response and damage of underground structures
- Structural damage under repeated dynamic loads
- Dynamic rock support
- Blasting vibrations
- Penetration and Impact
- Seismic design
- Dynamic issues in deep underground engineering
- Rock fragmentation and excavation
- Instrumentation and monitoring
- Engineering applications and case studies

Email: RocDyn-4@aconf.org

ISFOG 2020 4th International Symposium on Frontiers in Offshore Geotechnics, 28 – 31 August 2022, Austin, United States, www.isfog2020.org

16th International Conference of the International Association for Computer Methods and Advances in Geomechanics – IACMAG
30-08-2022 – 02-09-2022, Torino, Italy
www.iacmag2022.org

The aim of the conference is to give an up-to-date picture of the broad research field of computational geomechanics. Contributions from experts around the world will cover a wide range of research topics in geomechanics. The conference program will include plenary lectures, mini-symposia, selected oral and poster presentations.

Sessions/mini symposia

Parallel sessions:

- PS1 - Laboratory and field testing
- PS2 - Monitoring and remote sensing
- PS3 - Constitutive modelling
- PS4 - Coupled T-H-M-C processes
- PS5 - Multiphase modelling
- PS6 - Reliability and risk analysis
- PS7 - Surface and near surface structures: excavations, foundations, tunnels
- PS8 - Deep structures: tunnels, caverns
- PS9 - Dams and earth structures
- PS10 - Natural slopes
- PS11 - Coastal engineering
- PS12 - Mining engineering
- PS13 - Earthquake and dynamics
- PS14 - Soil-atmosphere interaction
- PS15 - Ice mechanics
- PS16 - Landfills and waste disposal
- PS17 - Ground improvements, reinforcement, geosynthetics
- PS18 - Preservation of historical sites
- PS19 - Gas and petroleum engineering
- PS20 - Underground storage of petroleum, gas, CO_2 and nuclear waste
- PS21 - Geothermal energy
- PS22 - Offshore technology
- PS23 - Energy geostructures

Mini Symposia:

- MS1 - Complex formations with a block-in-matrix fabric and field testing
- MS2 - Quantification and reduction of uncertainty in geomechanical numerical models
- MS3 - Computational rail geotechnics
- MS4 - Advanced constitutive modeling of soils in practical applications
- MS5 – Large strain problems in geomechanics
- MS6 - Building and infrastructure response to ground movement

- MS7 - Material Point Method in Computational Geomechanics
- MS8 - Probabilistic site characterization and data analytics
- MS9 - Validation of Numerical Modeling Techniques for Analysis of Soil-Liquefaction and its Consequences
- MS10 - Inverse analysis for parameter calibration and assessment of model perfomances

Organizing Secretariat

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11TH INTERNATIONAL SYMPOSIUM FIELD MONITORING IN GEOMECHANICS

September 4 - September 7, 2022, London, UK
https://isfmg2022.uk

It is my very great pleasure and honour to welcome you to the official website of the 11th International Symposium on Field Monitoring in Geomechanics (ISFMG). As the name suggests this event is part of a series of Symposia that have been staged roughly every four years since the early 1980s. Originally titled FMGM (Field Measurements in Geomechanics) the name was recently changed when responsibility for organising the Symposia passed to the newly formed TC220 (part of the International Society of Soil Mechanics and Geotechnical Engineering, ISSMGE). This was to avoid any conflict with the work of other technical committees that deal with in situ testing of soils and rocks. The purpose of TC220 is to address field monitoring, which is the repeated observation in time of a process or phenomenon through the measurement of one or more indicators. You will find more information at www.field-monitoring.org.

In 1948, when addressing the 2nd International Conference on Soil Mechanics and Foundation Engineering in Rotterdam, Karl Terzaghi wrote, *"Compared to this task (of field observations) all the other types of fundamental soil mechanics research such as refinement of our theoretical methods and laboratory techniques become of secondary importance. All these and various other observations convey the impression that the properties of undisturbed clays are more complex than laboratory tests on undisturbed clay samples indicate. Hence, the further advance of our knowledge in soil mechanics depends to a large extent on the scope and the quality of our field observations."* When presenting his ideas on The Observational Method in his 1969 Rankine Lecture, Terzaghi's friend and colleague Professor Ralph Peck said, *"However the field observations are made and whether they are elaborate and precise or 'quick and dirty,' the results are only useful if they are displayed promptly in such a manner as to show quickly and clearly the essential features. The reports containing the results should be regarded as working documents, issued whenever the information needs to be brought up to date."* These two statements capture perfectly why field monitoring is assuming ever greater importance in many construction projects around the world. Advances in technology have made it possible to collect and present measurements very quickly, enabling decisions to be made in near real-time. This Symposium will bring together designers, suppliers, users, and researchers of field monitoring data to discuss all that is new in field instrumentation and monitoring.

All conferences and symposia should have a theme and for this one we have chosen "analysis and interpretation of field monitoring data." In a letter I received when I accepted the role as Chair of this event, Professor Shunsuke Sakurai (Convenor of the 2nd International Symposium, Kobe Japan 1987) wrote "Field measurement data are only numbers unless they are properly interpreted. Therefore, the most important aspect of field measurements is the quantitative interpretation of measurement results."

At the Symposium we will inaugurate the ISSMGE Dunnicliff Honour Lecture to be given by Allen Marr (CEO of Geocomp Inc.). John Dunnicliff was an inspirational leader in this subject and it is very fitting that he will be remembered and honoured in this way. There will also be presentations from across a wide range of applications including slopes, tunnels and other types of construction. We will run the now traditional Young Person's Paper Competition and announce the venue for the next Symposium in 2026. As always the Symposium will be accompanied by an exhibition where you will get the opportunity to see all that is new in field instrumentation and catch up with representatives of the major suppliers.

Field instrumentation is uniquely able to answer the questions that geotechnical engineers ask. This will be a live face-to-face Symposium and the programme will include Special Lectures, Technical Presentations, Young Engineers Paper Competition, Poster Sessions, Exhibitions, Workshops and Technical Tours, as well as a parallel non-technical programme.

The theme of the symposium is data analysis and interpretation and the subjects are.

- *Tunnels and Underground Spaces*
- *Bridges and Transport Infrastructure*
- *Dams and Embankments*
- *Slopes and Earthworks*
- *Buildings and Foundations*
- *Mining and Landfill*
- *Environmental Monitoring*
- *The Observational Method*
- *Specifications and Standards*

Congress Organisers:
In Conference Ltd, UK
Q Court, Quality Street,
Edinburgh, EH45BP
Tel. +44 (0) 131 336 4203
Email us: ISFMG@in-conference.org.uk

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The 17th Danube - European Conference on Geotechnical Engineering

5-7 September, 2022, Bucharest, Romania
https://sites.google.com/view/17decgero/home

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Eurock 2022 Rock and Fracture Mechanics in Rock Engineering and Mining, 12÷15 September 2022, Helsinki, Finland, www.ril.fi/en/events/eurock-2022.html

IAEG XIV Congress 2022, Chengdu, China September 14-20, 2022, https://iaeg2022.org

28th European Young Geotechnical Engineers Conference and Geogames, 15 – 17 – 19 September 2022, Moscow, Russia, https://www.eygec28.com/?

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AUSROCK CONFERENCE 2022

6th Australasian Ground Control in Mining Conference – AusRock 2022

29 November-1 December 2022, Melbourne, Australia

Embracing the opportunity to provide world-leading professional development and networking opportunities to the global resources community, we are excited to announce the **AusRock Conference will be delivered in a hybrid event format**. Delegates will now be able to attend in person or access the conference content wherever they are in the world.

AusRock 2022 follows on from earlier conferences that have successfully covered the various aspects of geotechnical engineering servicing the mining industry and shared best practices.

The conference is a vehicle for information exchange between the coal and metalliferous sectors of the industry with a focus on new technologies and developments, industry needs and mine site problem solving, and practical case studies.

Conference themes

- Ground Control and Support
  - Tendon systems, surface liners, injection systems in open cut and underground mining
  - Alternative materials in ground support
  - Backfill technologies
  - Mine subsidence – prediction and control
  - New challenges and innovations in ground control
- Rock Mechanics in mining, civil and petroleum engineering
  - Rock mass characterisation techniques and practice
  - Jointed rock mass behaviour
  - Drilling, blasting and excavation
  - Tunnelling and underground space development
- Structure stability
  - Regional stability
  - Pillar design and performance
  - Slope stability
  - Tailings performance and management
  - Fracture diagnostics and surveillance: new technologies and methods
- Dynamic events and managing large deformations
  - Rock and coal burst
  - Induced seismicity
  - Wind and air blast
  - Water in-rush
- Geotechnical instrumentation
  - Underground and open pit monitoring techniques and performances
  - Monitoring for unconventional gas and petroleum
- Data management
  - Artificial intelligence applications
  - Data visualisation
  - Data analytics
  - Data driven decision making
- Mining Systems and Design
  - Geotechnical considerations
  - Geotechnical design methodologies
  - Caving mechanics and control
  - Multiseam, multireef and complex orebodies
- Geotechnical challenges in extreme environments
  - Deep mining
  - Underwater mining
  - Severe climate conditions
  - Planetary rock mechanics
- Interdisciplinary
  - Geothermal considerations
  - Subsurface storage and sequestration
  - Coupled behaviour
  - Pore pressure and fracture gradient
  - Petrophysics, Rock Physics, Geophysics for Geomechanics
  - Interdisciplinary aspects of theory, performance, and interpretation
- Geotechnical risk management
- Geotechnical education & training
  - Skills shortage and future needs
  - Professional ethics

Contact us by phone
T: 1800 657 985 or +61 3 9658 6100 (if overseas)

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10th International Conference on Physical Modelling in Geotechnics (ICPMG 2022), September 19 to 23, 2022, KAIST, Daejeon, Korea, https://icpmg2022.org

11th International Conference on Stress Wave Theory and Design and Testing Methods for Deep Foundations, 20 - 23 September 2022, De Doelen, Rotterdam, The Netherlands, https://www.kivi.nl/afdelingen/geotechniek/stress-wave-conference-2022

10th Nordic Grouting Symposium
https://www.ngs2022.se/

The Swedish Rock Engineering Association have the pleasure to invite you to the 10th Nordic Grouting Symposium which will be held at Stockholm City Conference Center.

Conference Themes

Grouting design and concepts for grouting
- Grouting Strategy
- Theory in relation to practice
- Novel methods for grouting execution
- Aspects that govern grouting – grouting difficulty
- Completion criteria for grouting
- Investigations of steering parameters for grouting
- Concepts with environmental aspects

Grouting materials
- Grout components
- Grout mixing
- Grout characteristics
- Environmental aspects – greener grouting

Soil- and Rock grouting
- Grouting the zone between soil and rock
- Grouting with low rock coverage

Grouting design verification
- Measuring the grouting result
- Observational method
- Hydrogeology
- Hydraulic tests
- Environmental permit

Case studies
- Execution of grouting and results

…

Grouting Equipment
- Development of grouting equipment
- Possibilities and limitations of current equipment
- Health and safety

Grouting contracts and compensation
- Time studies of grouting work
- Grouting compensation and adjustment of time
- Grouting education – Licence to Grout

Contact info

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Box 55545, 102 04 Stockholm, Sweden
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url: www.svbergteknik.se

IX Latin American Rock Mechanics Symposium - Rock Testing and Site Characterization, an ISRM International Symposium, 16-19 October 2022, Asuncion, Paraguay, http://larms2022.com

AUSROCK Conference 2022, 6th Australasian Ground Control in Mining Conference –an ISRM Regional Symposium, 29 November – 1 December 2022, Melbourne, Australia, www.ausimm.com/conferences-and-events/ausrock/

4th African Regional Conference on Geosynthetics – Geosynthetics in Sustainable Infrastructures and Mega Projects, 20-23 February 2023, Cairo, Egypt, www.geoafrica2023.org

88th ICOLD Annual Meeting & Symposium on Sustainable Development of Dams and River Basins, April 2023, New Delhi, India, https://www.icold2020.org

17th Asian Regional Geotechnical Engineering Conference
14-18 August 2023, Nur-Sultan, Kazakhstan

Organiser: Kazakhstan Geotechnical Society;
Contact person: Ms. Bibigul Abdrakhmanova;
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XII ICG - 12th International Conference on Geosynthetics, September 17 – 21, 2023, Rome, Italy, www.12icg-roma.org

International Congress in Rock Mechanics
Challenges in Rock Mechanics and Rock Engineering

9÷14 October 2023, Salzburg, Austria
https://www.isrm2023.info/en/

The Austrian Society for Geomechanics has the pleasure to invite you to the 15th ISRM Congress 2023 to be held in conjunction with the 72nd Geomechanics Colloquium in Salzburg, the city where the International Society for Rock Mechanics (ISRM) was founded in 1962. The Geomechanics Colloquium in Salzburg since its initiation in 1951 has always been a perfect and distinguished meeting place for researchers and practitioners. The success of this concept not only shows in the continuous meetings over more than 70 years, but also in the attendance of regularly around 1000 participants.

Preliminary topics

The following topics are currently planned:

- Deep geothermal energy
- Underground storage for liquid and gaseous media
- Geological risks and natural hazards
- Long term behaviour of underground structures
- Challenging rock engineering projects
- Digitalization & Automatisation
- Monitoring
- Numerical methods in rock engineering
- Geological investigation and characterization
- New developments in rock support
- NATM versus TBM
- Comparison of international tunnelling contracts
- Hydropower projects and dams
- Rock and rock mass properties
- Mining engineering
- Petroleum engineering and carbon sequestration
- Early Career Forum (Young Researchers)

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XVIII European Conference on Soil Mechanics and Geotechnical Engineering

25-30 August 2024, Lisbon, Portugal

Organiser: SPG
Contact person: SPG
Address: Av. BRASIL, 101
Email: spg@lnec.pt
Website: http://www.spgeotecnia.pt

ΕΝΔΙΑΦΕΡΟΝΤΑ ΓΕΩΤΕΧΝΙΚΑ ΝΕΑ

This is what a rockfall looks like in the Himalayas. It's scary

[Pietro Kopiewski · 7-26](https://www.tiktok.com/@kopiewski/video/6989102307757608193), https://www.tiktok.com/@kopiewski/video/6989102307757608193

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George County: a drone video of the site of a fatal landslide triggered by Hurricane Ida

The landfall of Hurricane Ida across the southern USA earlier this week caused high levels of rainfall, inducing flooding and landslides. In terms of mass movements, one of the most significant events occurred in the Benndale community in George County in Mississippi, where a substantial failure destroyed a section of MS26. The landslide had substantial consequences – it killed two people and injured a further 10, three of them critically.

The Sun Herald has a detailed article about the event, and has published a drone video of the aftermath. The site is quite interesting, as this overhead view shows:

The fatal landslide in George County, Mississippi. Image taken from a drone video posted by the SunHerald. Drone video by Travis Long.

The view below, also from the drone video, provides an understanding of the form of the landslide:

An oblique view of the fatal landslide in George County, Mississippi. Image taken from a drone video posted by the SunHerald. Drone video by Travis Long.

The SunHerald article provides some information about the landslide:-

"It is a slide, which means the ground under the roadway and embankment was super-saturated and we can tell right now that's what caused the slide," said Kelly Castleberry, district engineer for the Mississippi Department of Transportation. "The ground liquified and it spread several hundred feet to the south."

Castleberry said the drone footage shows a path created by groundwater, which is beneath the earth, not surface water…He said groundwater from all the rain, a water-line leak, or both, could have caused the collapse that killed two people and injured 10, three of them critically. MDOT is investigating the cause and will have an update when more information is available, Castleberry said.

The road appears to be on embankment, which has failed.

(Dave Petley / THE LANDSLIDE BLOG, 1 September 2021, https://blogs.agu.org/landslideblog/2021/09/01/george-county)

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Shimla landslide

Shiv Aroor, @ShivAroor, https://twitter.com/ShivAroor/status/1434756431484387331

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Natural Hazards 101: Forecasting and modelling

With the Natural Hazards 101 series, we mean to bring our readers closer to the terminology often used in the field of natural hazards, but that may not be so familiar.

In the first episode of the series, we focused on the definition of hazard and natural hazard. We moved then to the concept of risk, which brought us to define exposure and vulnerability. Later on, we digested the disaster terminology provided by the United Nations Office for Disaster Risk Reduction. In this episode, we will explore the meaning of "Forecasting and modelling" natural hazards.

It is hard to find an official or commonly accepted definition of "Natural hazard modelling" since models can be applied in different scientific fields besides natural hazards and geosciences. If you search on the web, it is easy to find that **modelling (and simulating)**, in science, is defined as a scientific activity aimed to make a phenomenon easier to understand, define, quantify, visualize, or simulate by referencing it to existing and usually commonly accepted knowledge. All models are thus reflections of reality that, despite being approximations, can be extremely useful [1].

Models are typically used when it is either impossible or impractical to create experimental conditions in which scientists can directly measure outcomes. They are generally cheaper, safer and sometimes more ethical than conducting real-world experiments. Simulations can often be performed faster than the real-time phenomena they describe [2].

Scientific models can be divided in:

Physical models: smaller and simpler representations of the phenomenon or object being studied. A globe or a map is a physical model of a portion or all of Earth.

Mathematical models: sets of equations that take into account many factors to represent a phenomenon. Mathematical models are usually done on computers. Among them, statistical models based on Machine Learning algorithms are currently finding a growing application.

Concerning natural hazards, GNS Science provides a synthetic description of their geohazard modelling activity [3]. This activity can be representative of the typical approach adopted by scientists to model natural hazards.

- **Earthquake Hazard Modelling**: they model strong quakes to determine and design for the severity and characteristics of strong ground shaking.
- **Landslide Hazard Modelling**: they forecast the magnitude and frequency of new and pre-existing landslides in response to event scenarios (for example, rainstorms or earthquakes).
- **Tsunami Hazard Modelling**: they use hydrodynamic models that provide quantitative estimates of the propagation of tsunami waves away from their source and their impact when they reach the coast.
- **Volcano Hazard Modelling**: they provide a dynamic assessment of the likelihood of size, frequency and location of future eruptions, based on the current level of volcanic unrest, coupled with analysis of past historic and geologic data.

In the context of the disaster cycle, as described in the latest episode of the series, natural hazards modelling can be considered a non-structural measure that contributes to mitigating risk and developing preparedness. Natural hazards modelling is also at the basis of disaster risk assessment. The UN Office for Disaster Risk Reduction (UNDRR) describes modelling as a qualitative or quantitative approach to determine the nature and extent of disaster risk, including identifying potential hazards and their characteristics, such as their location, intensity, frequency and probability [4].

Finally, natural hazards modelling is propaedeutic to **natural hazards forecasting**. The latter is a complex science that aims to determine where, when, and how intensively the next natural hazard event will occur. Scientists attempt to predict natural hazards and their consequences using a variety of approaches, which can be loosely grouped into two broad categories: theoretical (mechanistic, deterministic, physically based, "hard") and empirical (statistical, functional, "soft") approaches. Unlike other natural phenomena, natural hazards are difficult to predict since they are typically chaotic or exhibit distinct nonlinear behaviours, complicating the possibility of using past occurrences to predict future events [5]. However, low predictability is different from unpredictability [6], and efforts should be made to improve our ability to forecast natural hazards and determine and communicate the uncertainties of such forecasts [5].

References

[1] https://en.wikipedia.org/wiki/Modeling_and_simulation

[2] https://en.wikipedia.org/wiki/Scientific_modelling

[3] https://www.gns.cri.nz/Home/Our-Science/Natural-Hazards-and-Risks/Risk-Society/Risk-Modelling/Hazard-Modelling

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[5] Guzzetti, F. (2016). Forecasting natural hazards, performance of scientists, ethics, and the need for transparency. Toxicological & Environmental Chemistry, 98(9), 1043-1059. https://dx.doi.org/10.1080%2F02772248.2015.1030664

[6] Stein, J. L., & Stein, S. (2014). Gray swans: comparison of natural and financial hazard assessment and mitigation. Natural hazards, 72(3), 1279-1297. https://dx.doi.org/10.1007/s11069-012-0388-x

Read episode 1: What is a -natural- hazard?

Read episode 2: The concept of risk.

Read episode 3: The disaster cycle.

(Gabriele Amato / EGU Blogs - Divisions - Natural Hazards, September 6, 2021, https://blogs.egu.eu/divisions/nh/2021/09/06/natural-hazards-101-forecasting-and-modelling)

Network Rail and HS2 look to fibre optic technology to monitor railways

Both Network Rail and HS2 Ltd have announced trials involving fibre optic technology to improve their monitoring systems.

HS2's trial will focus on monitoring ground movements in embankments and cuttings, and could help prevent land slips and detect the formation of sink holes.

Meanwhile Network Rail's separate trial will use Fibre Optic Acoustic Sensing (FOAS) technology to improve train movement and position reporting; detect rail and wheel defects; support level crossing safety management; and detect trespassers and people on the trackside.

HS2 trial

University of Cambridge's Centre for Smart Infrastructure & Construction (CSIC) and geosynthetics manufacturer HUESKER have combined to lead on the HS2 project, which also includes main civils contractor Align and Jacobs.

The technology being trialled is called Sensorgrid and the team estimates that its use could save millions of pounds in repairs due to avoiding early ground movements.

The first stage of the trial has already taken place at HS2's Chilterns tunnel south portal site. Heavy-duty water-filled bags were laid in the base of the pit, sections of the Sensorgrid were laid over it and then buried.

Monitoring equipment then generated pulses of light that travelled through the fibre optic cable. To simulate ground movement, water was released from the bags causing the weight of the ground above to move and strain the mesh which in turn causes a change in characteristics of the light pulsing through it.

The technology is now undergoing a full scale live trial elsewhere at HS2's South Portal site near the M25 motorway. Two kilometres of Sensorgrid has been incorporated into a cutting for the railway. It will provide continuous data to the monitoring team over the next two years.

HS2 Ltd innovation manager Rob Cairns said: "Sensorgrid is a great example of how we're leveraging HS2's size and scale to draw on British expertise to develop a technology and demonstrate its innovative capability in the early stages of construction. This will act as a test bed for proving out significant benefit to the operational railway, with long term benefits in bolstering the resilience of the UK's transport network."

Align's innovation manager, Nick Podevyn said:

"A lot of hard work has gone into this innovation, which has been in incubation for more than a year. It has been an exemplar of open collaboration and working as one team to deliver the solution. It's fantastic to see the prototype being physically tested on our site and then the technology being implemented on the live project."

CSIC Operations Manager, Cedric Kechavarzi said:

"Sensorgrid opens a wealth of new opportunities to use fibre optic sensing in geotechnical applications, as it vastly improves strain transfer from the soil to the sensor."

Network Rail trial

Thales Ground Transportation Systems Ltd has been awarded a contract by Network Rail to develop and trial Fibre Optic Acoustic Sensing (FOAS) technology that will support improvements in safety and performance on the railway.

The awarding of the contract follows a Design Contest launched in November 2020, led by Network Rail in collaboration with Dutch rail infrastructure operator ProRail, which challenged over 40 suppliers of different sizes to come up with proposals for a funded 12-month outcome-focused trial of FOAS, IoT sensors and smart CCTV cameras, amalgamated through intelligent data fusion and processing.

The trial work with Thales' successful bid – featuring a consortium comprising SMEs to deliver different parts of the technology – will be conducted at Network Rail's RIDC Melton test track, and on the mainline railway from Melton Mowbray to Leicester, commencing in Autumn 2021.

Network Rail's R&D portfolio programme manager Huw Evans, said: "This is a brilliant example of collaboration between Network Rail and ProRail to research and develop solutions to problems that are common to us both, and we look forward to working closely with the Thales-led consor-tium.

"RIDC Melton and the adjacent main line provide the perfect

operational scenarios for us to safely and expertly test the technology and fully evaluate its potential."

(Rob Horgan / New Civil Engineer, 08 Sep, 2021, https://www.newcivilengineer.com/latest/network-rail-and-hs2-look-to-fibre-optic-technology-to-monitor-railways-08-09-2021)

Paimio: a very unusual landslide in Finland

Last week a very unusual and interesting landslide occurred close to the town of Paimio in Finland. The image below, published on ts.fi, provides a wonderful overview of the landslide:-

The landslide at Paimio in Finland.

Once again I don't think I've seen one quite like this before. The source area appears to be an aggregate store from a nearby quarry. The aggregate pile has has clearly failed – there is a scar and some tension cracks visible. The material in the fields appears to be clay, common in formerly glaciated areas. The failure of the aggregate pile has propagated through the clay substrate over a distance of perhaps 100 metres, forming a set of compressive ridges. This is unusual.

It is interesting to ponder what might have happened here. My working hypothesis is that this might be a bearing capacity failure in the clay below the aggregate pile – essentially the clay did not have the shear strength to withstand the stresses imposed by the heap. Its failure caused the pile to collapse.

The nearest comparative event I can remember of the Hatfield Colliery failure close to my now home in Sheffield, in England. In this case colliery spoil was piled on gravels that subsequently failed. However, in the case of the landslide at Paimiossa the failure has propagated a relatively longer distance from the source, presumable reflecting the properties of the clay.

Fortunately no-one was killed or injured in the landslide at Paimiossa, and only one building was damaged.

The location of the landslide is, I believe, 60.434, 22.610. There is a Google Earth image of the site from 2018:-

Google Earth image of the site of the landslide at Paimio in Finland.

Interestingly this image does not show the large pile of aggregate that was involved in the failure, so this might be a comparatively recent addition.

Acknowledgement

Many thanks to loyal reader Tomi for highlighting this one to me.

(Dave Petley / THE LANDSLIDE BLOG, 9 September 2021, https://blogs.agu.org/landslideblog/2021/09/09/paimio-a-very-unusual-landslide-in-finland)

Huge boulders break off a mountain near Mexico City, plunging into a densely populated neighborhood

A part of a mountain in Tlalnepantla, located on the outskirts of Mexico City, gave way on Friday, Septem-

ber 10, 2021, sending huge boulders -- some of them the size of small homes -- into a densely populated area, and leaving at least 1 person dead and 10 missing.

The landslide followed days of heavy rain in central Mexico and M7.0 earthquake on September 7 in Acapulco[1]. Mexico state Gov. Alfredo del Mazo said Friday night that both factors likely contributed to the slide.

Residents immediately started search and rescue operations and continued until the night when authorities pulled them off due to the risk of more landslides.

"We don't want to anyone to take additional risk," said Ricardo De La Cruz, Mexico state's deputy interior secretary. "The geologists have told us that the landslide is complicated. We have made flights with drones and we don't want to put anyone in danger."[2]

De La Cruz added that the priority on Saturday was to stabilize the slope and continue the search. However, the likelihood of finding survivors is falling as rescuers with dogs and sensitive equipment did not detect anything under the rubble.

Images from the area showed a segment of the steep, green side of the peak known as Chiquihuite sheared off above a field of giant rubble with closely packed homes remaining on either side.[3]

References:

[1] Very strong and shallow M7.0 earthquake hits near Acapulco, Mexico - The Watchers

[2] Landslide near Mexico City leaves 1 dead, 10 missing - CBC

[3] At least 1 dead, 10 missing in landslide near Mexico City - AP

https://www.youtube.com/watch?v=g0Ln8UYRufU

https://www.youtube.com/watch?v=JjyRRDfGyyw

(THE WATCHERS, September 12, 2021, https://watchers.news/2021/09/12/tlalnepantla-landslide-mexico-city-september-2021)

☙ ❧

Rare phenomenon blamed for Michigan dam collapse

Figure 20: Edenville left embankment breach at 7:13 p.m. on Tuesday, May 19, 2020

A "rare" type of ground failure led to the dramatic collapse of a Michigan dam that sparked the evacuation of 10,000 people last spring, an official report has found.

An independent forensic team commissioned by the US Federal Energy Regulatory Commission (FERC) this week said static liquefaction was the most likely cause of the breach of the Edenville Dam on 19 May 2020.

The team's interim report described "strong evidence" that this phenomenon – whereby saturated loose sandy soil under shear pressure suddenly loses strength – was behind the incident.

"This failure mechanism has been rare but not unprecedented for water storage dams," said the study. "Water storage dam engineers have not typically considered it.

"It has generally been assumed by geotechnical engineers that, under loading conditions other than earthquakes, water will be able to flow in and out of sands and their strength will be defined by the drained shear strength, regardless of the density of the sand – ie there will be no dramatic strength reduction as occurs in static liquefaction."

After water breached the Edenville Dam on the Tittabawassee River, it soon overwhelmed the downstream Sanford Dam, leading to major flooding and residents being forced out of their homes in nearby towns.

"The physics of the Sanford Dam failure are very clear," said the report. "The failure was the result of embankment overtopping. Regulators and engineers understood that should a breach occur at Edenville, Sanford would almost certainly be overtopped and fail."

The Edenville and Sanford Dams were two of four 1920s-built dams along the Tittabawassee River in Michigan owned at the time of the failures by Boyce Hydro Power.

The dams consisted of earthfill embankments, gated concrete spillways, powerhouses, and, in the case of Sanford Dam, a fuse plug spillway. At the time of the failures, Sanford Dam was an active hydroelectric facility, while Edenville's powerhouse was inactive because its FERC licence had been revoked.

(Greg Pitcher / GROUND ENGINEERING, 16 September, 2021, https://www.geplus.co.uk/news/rare-phenomenon-blamed-for-michigan-dam-collapse-16-09-2021)

Strathclyde exploring fungi to prevent landslips

Researchers at Strathclyde University are exploring the use of fungi in strengthening soil and reducing infiltration of rainwater, a common cause of landslips.

The project will use fungi and soil collected from the UK and Italy to understand how the growth of different fungal species can be controlled to improve the engineering performance of natural soils.

Lead researcher Dr Grainne El Mountassir, a senior lecturer in Strathclyde's Department of Civil and Environmental Engineering, has received a UKRI Future Leaders Fellowship worth £1.3m over four years for the project. Cardiff University, the University of Naples Federico II and engineering company BAM Ritchies are also partners in the study.

"Our research aims to understand the factors controlling fungal growth in natural soils, such that we can engineer it to grow over a large area," El Mountassir said. "We will be examining different types of soil, including pyroclastic soil which originated from eruptions of Mount Vesuvius, and looking at how fungal growth changes soil cohesion."

El Mountassir explained how the fungus builds a 3D network of biomass which acts both to bind soil particles together but also releases products that can modify how water moves through soil.

The idea of the study, she said, is to create a biological geotextile at the soil surface which could reduce the ability of water to penetrate into soil, improving the stability of slopes after heavy rainfall.

"Fungi are incredibly resilient and adaptable," she commented. "Fungi on the floors of North American forests are believed to be some of the oldest living organisms of Earth, with individual organisms dated as around 1500 years old.

"We know a lot about the uses of fungi in making food and drink, such as bread and beer, but we know relatively little about them in other contexts.

"The research is part of a transition towards a more sustainable, low-carbon civil engineering sector and as a growth-based system, it would reduce the amount of materials needing to be transported to site."

(THE ENGINEER, 20th September 2021, https://www.theengineer.co.uk/strathclyde-exploring-fungi-to-prevent-landslips)

The Role of Liquefaction on the Seismic Response of Quay Walls during the 2014 Cephalonia, Greece, Earthquakes

Georgios Zalachoris, Dimitrios Zekkos, Adda Athanasopoulos-Zekkos, and Nikos Gerolymos

Abstract

Following the Cephalonia, Greece, 2014 earthquake sequence (*Mw*=6.1 and *Mw*=6.0), liquefaction of gravelly earthfill materials at the ports of Lixouri and Argostoli resulted in the manifestation of ground cracking and coarse-grained soil ejecta, and the quay walls in these ports exhibited lateral ground displacements ranging from 0.1 to 1.5 m. To evaluate the seismic performance of the port quay walls, numerical analyses using the finite-difference method were performed, and the results compared with the observed response. Three commonly used constitutive models (PM4Sand, UBCSand, and URS/ROTH) calibrated based on in situ site investigation data were considered in modeling the liquefiable earthfills. The results of the numerical analyses at both ports using the best-estimate parameters indicate that taller walls exhibit smaller lateral ground displacements than shorter walls, something that is in line with field observa-

tions. For the shorter walls, liquefaction-induced lateral spreading played an important role in the observed response, whereas for the taller walls, the seismic behavior is dominated predominantly by the dynamic response of the structural system. PM4Sand and UBCSand models seem to yield very similar deformational results, but the URS/ROTH model, which assigns residual shear strength parameters once liquefaction is triggered, resulted in horizontal displacements that are closer to the observations for short-wall geometries but overpredict the response when the effect of liquefaction on the overall displacements is small. Finally, the numerical analyses demonstrate the strong influence of the pulselike characteristics, as well as the polarization of the input motion on the seismic response of the Lixouri quay walls, indicating that forward directivity contributed significantly to the observed quay wall deformations.

https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29GT.1943-5606.0002662

A New Dynamic Cone Penetration Test–Based Procedure for Liquefaction Triggering Assessment of Gravelly Soils

Kyle M. Rollins, Jashod Roy, Adda Athanasopoulos-Zekkos, Dimitrios Zekkos, Sara Amoroso and Zhenzhong Cao

Abstract

Developing a reliable, cost-effective liquefaction triggering procedure for characterizing the liquefaction potential of gravelly soils based on in situ penetration testing has always been a great challenge for geotechnical engineers and researchers. Typical correlations based on the standard penetration test (SPT) and the cone penetration test (CPT) are affected by large-size gravel particles, which can lead to erroneous results. The Becker Penetration Test, well known for gravelly soil characterization, is cost-prohibitive for routine projects and is not available in most of the world. With a cone diameter of 74 mm the Chinese dynamic cone penetration test (DPT) is superior to smaller penetrometers and can be economically performed with conventional drilling equipment. DPT has previously been directly correlated to field performance data, and probabilistic liquefaction resistance curves were developed based on one earthquake and geologic environment in China; however, the use of these data in other tectonic and geologic environments was not validated. In this study, 137 data points from 10 different earthquakes and different depositional environments in seven countries have been used to develop probabilistic liquefaction resistance curves. The data set was expanded by performing DPT soundings at sites around the world where gravelly soil did or did not liquefy in past earthquakes. Based on the expanded DPT database, a new set of magnitude-dependent probabilistic triggering curves has been developed using logistic regression analysis. The new triggering curves are better constrained by data and the spread between the 85% and 15% probability curves is reduced. Liquefaction resistance is shifted upward at lower DPT values. A new magnitude scaling factor (MSF) curve has also been developed specifically for gravel liquefaction which was found to be consistent with previous curves for sand.

https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29GT.1943-5606.0002686

(Sep 24, 2021, https://twitter.com/AZekkos/status/1441194684034871297?cn=ZmxleGlibGVfcmVjcw%3D%3D&refsrc=email)

The first fully scientific report ever produced about a major landslip

In 1840, Lyme geologists Rev William Conybeare and Dr William Buckland produced the first fully scientific report ever produced about a major landslip – the Bindon Landslip of 1839… (1/6)

It was beautifully illustrated with coloured maps and sections by William Dawson and engravings by Mary Buckland. Here is a dramatic excerpt from the report describing the midnight account of an on duty coast guard… (2/6)

"James Robertson and a companion were at that hour crossing the fields which then stretched along this tract; they stumbled across a slight ridge of gravel, which at first they thought only the work of mischievous boys… (3/6)

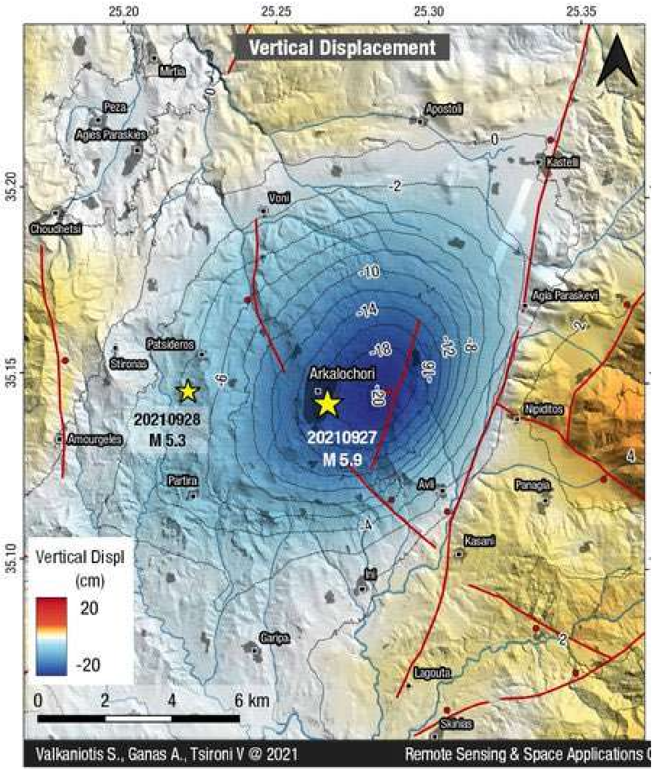
…but proceeding a few steps further one of them jambed his leg into a narrow fissure; when he was extricated they looked around in alarm, and observed more extensive fissures opened and opening in the same direction… (4/6)

… they experienced no tremulous motion and only heard noises which they describe as the rending of cloth; as their station was on Whitlands Cliff they soon cautiously picked their way out of this disturbed tract… (5/6)

… before the subsidence, of which they thus witnessed the initial disruption, had made any material progress in the depression of the surface; but by daybreak the next morning this depression is said to have been considerably advanced." (6/6)

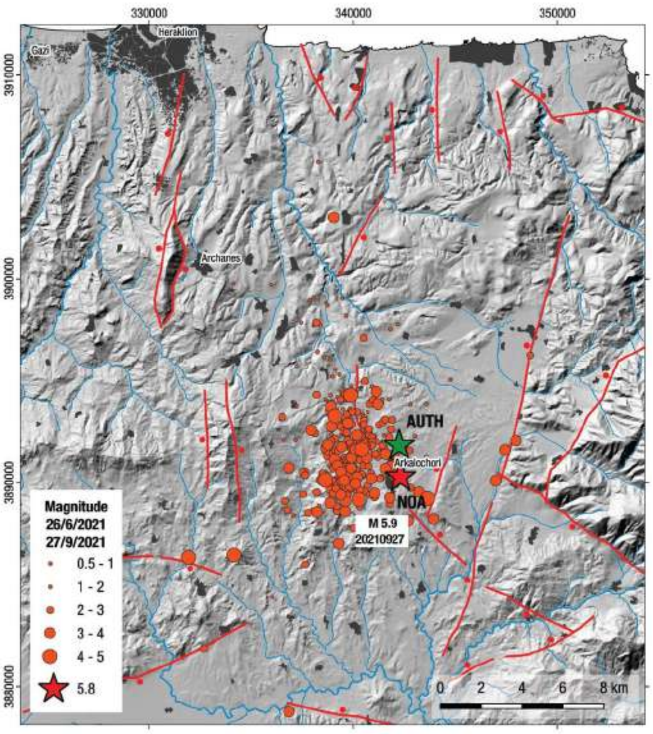
(Lyme Regis Museum, Sep 26, 2021, https://twitter.com/LymeRegisMuseum/status/1442208058776690702)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΣΕΙΣΜΟΙ & ΑΝΤΙΣΕΙΣΜΙΚΗ ΜΗΧΑΝΙΚΗ

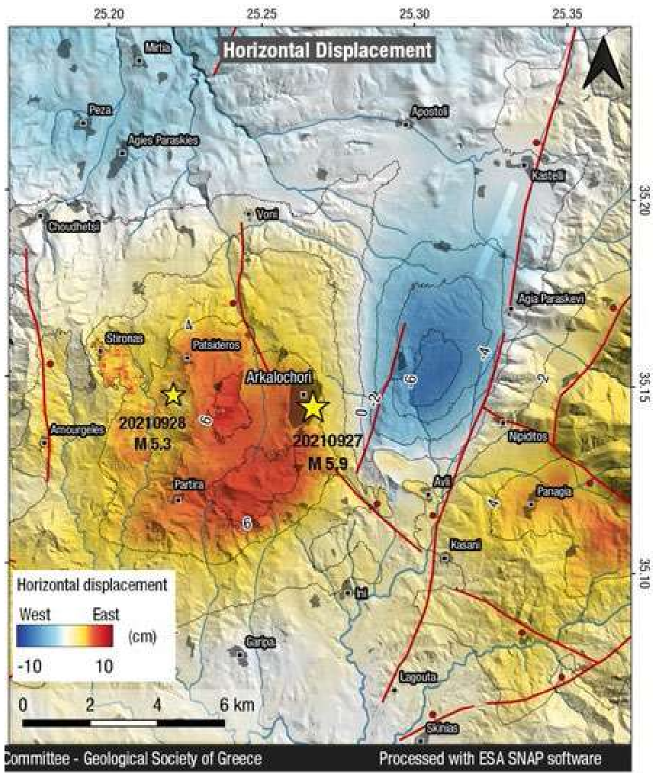


M5.9 earthquake in Crete

NOA (red) & AUTH (green) epicenters for the M5.9 earthquake in Arkalochori, Crete southeast of Iraklio city. Epicenters (orange) of the three month sequence (Jul-Sept) & early aftershocks from NOA catalogue.



(Sotiris Valkaniotis, @SotisValkan, Sep 27, 2021, https://twitter.com/SotisValkan/status/1442421600301760514)



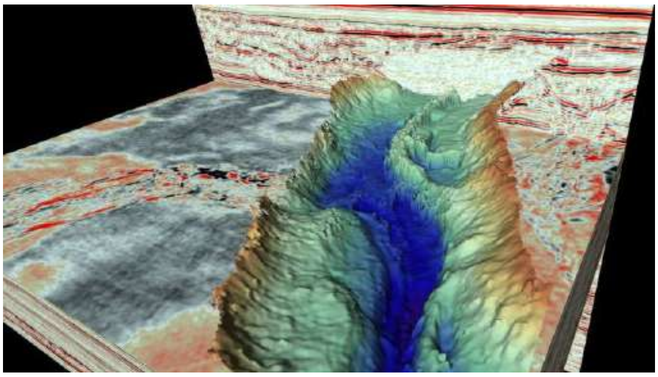
Deformation for the M5.9 earthquake in Crete

Deformation for the M5.9 earthquake in Crete, Greece, extracted from Sentinel1 interferogram decomposition (asc+desc). 20 cm of max subsidence near Arkalochori. Displacement pattern favors a west-dipping NNE-NE source fault. Epicenters from NOA, ifgs processed with SNAP.

(Sotiris Valkaniotis, @SotisValkan, Sep 30, 2021, https://twitter.com/SotisValkan/status/1443566071810859011)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΓΕΩΛΟΓΙΑ

Spectacular valleys and cliffs hidden beneath the North Sea



Scientists discovered this esker (a sedimentary cast of a meltwater channel formed beneath an ice sheet), in a tunnel valley beneath the North Sea floor. The landscape is shown in an image based on high-resolution 3D seismic data. (Image credit: British Antarctic Survey)

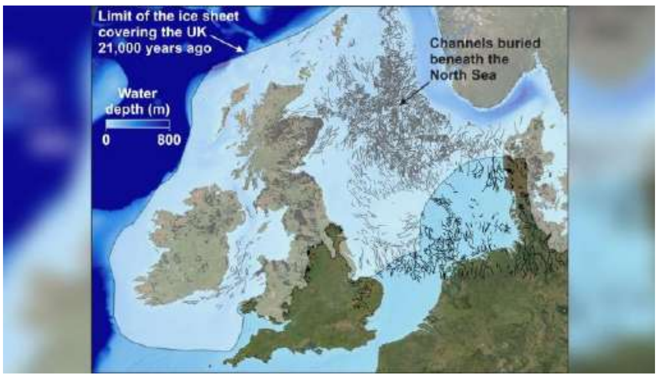
Like a bowl of spaghetti noodles spilled across the floor of the North Sea, a vast array of hidden tunnel valleys wind and meander across what was once an ice-covered landscape.

These valleys are remnants of ancient rivers that once drained water from melting ice sheets.

Now, scientists have achieved the clearest view yet of these channels. They're buried hundreds of feet beneath the seafloor, and they are enormous, ranging from about 0.6 to 3.7 miles (1 to 6 kilometers) wide.

The new imaging reveals fine-grained details within these expansive features: small, delicate ridges of sediment, larger walls of sediment that can be miles long and craters called kettle holes left behind by melting chunks of ice.

"We didn't expect to find these kinds of footprints of the ice sheet within the channels themselves," said study lead author James Kirkham, a marine geophysicist at the British Antarctic Survey and the University of Cambridge. "And that tells us, actually, that the ice was interacting with the channels a lot more than previously assumed."



A map of the North Sea showing the distribution of buried channels (tunnel valleys) that have been previously mapped using 3D seismic reflection technology.

Footprints of glaciers

These channels are the footprints of glaciers left behind from between 700,000 and 100,000 years ago, when most of the North Sea, as well as the northern two-thirds of the United Kingdom and all of Ireland were often buried under huge ice sheets. (The ice advanced and retreated seven or eight times within this period, Kirkham told Live Science.)

During periods when the climate warmed and the ice retreated, these ice sheets discharged water through hidden glacial channels beneath the ice. These channels left their imprint on the sediments below. More sediments then piled on top as the ice vanished, entombing the imprints deep beneath the seafloor.

To see these ancient impressions, geophysicists use a technology called 3D seismic reflection. In this process, scientists shoot bursts of compressed air toward the seafloor. The resulting sound waves travel through the rock and sediment layers beneath the seafloor and bounce back, where they're picked up by a shipboard receiver. Because sound travels at different speeds through different types of rock and sediment, the data can be reconstructed into a picture of the subsurface.

A map of the undersea tunnel valleys looks like a vast array of squiggles, like a scattering of spilled noodles. But zoomed in, the channels are visible in stunning detail. They meander and wind like rivers (which they once were), bounded by shear cliffs and rugged slopes. Some plummet 310 miles (500 km) deep into the sediment and are dozens of miles long.

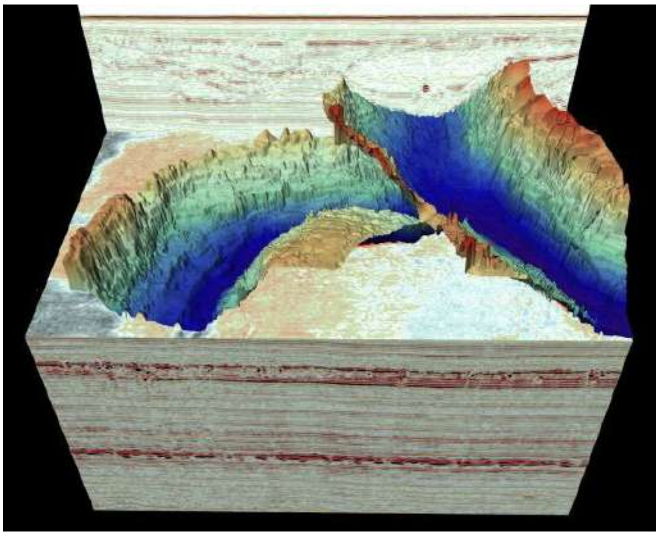
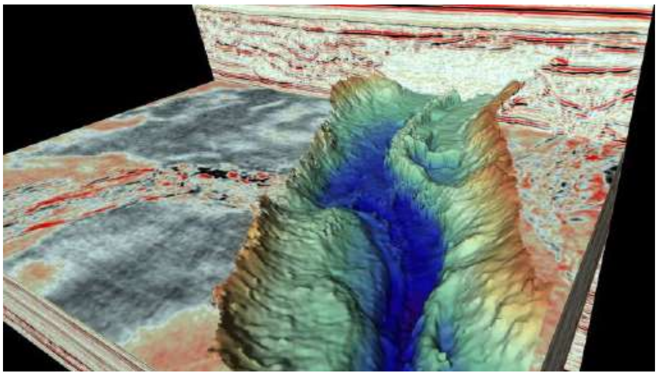


Image of two cross-cutting tunnel valleys discovered using the new 3D seismic reflection data. In this image, the channels are shown in context of the high-resolution 3D seismic data which can be 'sliced' both vertically and horizontally to reveal ancient glacial landscapes buried beneath the seafloor of the North Sea.



Scientists discovered this esker (a sedimentary cast of a meltwater channel formed beneath an ice sheet), in a tunnel valley beneath the North Sea floor. The landscape is shown in an image based on high-resolution 3D seismic data. (Image credit: British Antarctic Survey)

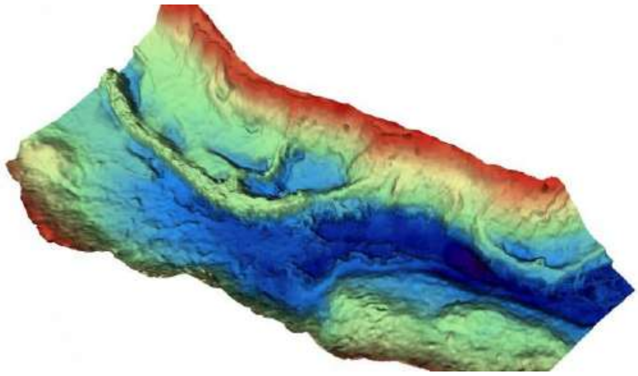


Image of an esker (a sedimentary cast of a meltwater channel formed beneath an ice sheet) that we have found within a tunnel valley using the new 3D seismic reflection data. (Image credit: British Antarctic Survey)

Water and ice

The landforms within the tunnel valleys paint a complicated picture of ice retreat, Kirkham said. At times, there are signs of fairly slow and steady retreat. For example, eskers are ridges of sediment around 16 feet (5 meters) high that can stretch for many miles. They're also seen in modern-day glaciers that are moving gradually.

In other spots, the channels are punctuated by small, delicate ridges that indicate fast, dynamic ice flow, Kirkham said. Another sign of fast-moving surges of ice and water are kettle holes, which are spots where a large iceberg that has detached from the main ice sheet and moved to a new location finally gets stuck and melts.

The channels seem to have been carved by both water and ice. In some spots, there are braided channels meandering through the bottom of the canyons, Kirkham said. These were formed by flowing water, which seems to have eroded the sediment beneath the ice sheet. Once that void formed, however, the underside of the ice sagged into that gap, carving out a broader path. There are also places where valley walls seem to have collapsed, probably after the ice that was filling the valley melted away, enabling the sediment to slump in its stead.

These undersea tunnel valleys are an interesting snapshot of the past, but their real value may be in helping to predict the future. As the climate warms, the ice caps are again on the retreat. If the climate gets hot enough, West Antarctica might someday look a lot like the North Sea did 100,000 years ago, Kirkham said. The Greenland ice sheet, too, is melting rapidly. Studying the remnants of the North Sea channels and how they formed could reveal more about the dynamics governing the loss of today's ice sheets. In particular, the geological record could hint at how small-scale factors like moving water affect how much ice ends up melting into the sea, and how quickly, which could lead to better models of sea-level rise.

"In the future, we'd like to explore that idea a bit further by continued mapping, and also some computer modeling to work out how we've produced these landforms and what would need to happen at the base of an ice sheet to generate them," Kirkham said.

The findings appear today (Sept. 8) in the journal Geology.

Originally published on Live Science

(Stephanie Pappas / LIVESCIENCE, September 10, 2021, https://www.livescience.com/north-sea-ice-age-tunnel-valleys.html)

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΠΕΡΙΒΑΛΛΟΝ

Το θαύμα της φύσης

Από τα καμένα του Αυγούστου, το θαύμα της φύσης σήμερα. Η φωτογραφία είναι των μέσων του Σεπτεμβρίου από το Πευκί Ευβοίας (της Έφης Παναγιωτοπούλου – Μαρίνου).

ΕΝΔΙΑΦΕΡΟΝΤΑ - ΛΟΙΠΑ

Bridge Load Test

(Civil Engineering Discoveries, 01.09.2021, https://twitter.com/CivilEngDis/status/1433129722377031684)

ΕΝΔΙΑΦΕΡΟΥΣΕΣ ΑΝΑΜΝΗΣΕΙΣ

Αιθιοπία και Λούσυ

Παύλος Μαρίνος

Η επίσκεψη έγινε το 2012.

Γράφθηκε το 2021

Είμαι εδώ για λογαριασμό μεγάλου Ελληνικού Μελετητικού Γραφείου προκειμένου να δώσω τεχνική άποψη για θέσεις για κατασκευή φραγμάτων που επισημάνθηκαν από το γραφείο.

Λούσυ, ο Αυστραλοπίθηκος

Το 1974, ανθρωπολόγοι έκαναν στην Αιθιοπία μια εκπληκτική ανακάλυψη, εντοπίζοντας τα οστά που ανήκαν σε ένα ον που είχε μεγάλες ομοιότητες με τον άνθρωπο και περπάτησε στον πλανήτη πριν από 3,2 εκατομμύρια χρόνια. Αυτό ήταν η Λούσυ. Άραγε, επρόκειτο για απευθείας πρόγονο του Homo Sapiens; ήταν η Λούσυ "η μητέρα του ανθρώπινου γένους'"; [1]

Ήδη το 1970, Γάλλοι παλαιοανθρωπολόγοι ανακάλυψαν στο Τρίγωνο Αφάρ απολιθώματα και χρηστικά αντικείμενα. Σχετικώς προσεκλήθησαν διάσημοι επιστήμονες, Να αναφέρουμε τον Donald Johanson, του μουσείου του Cleveland. Η αποστολή ξεκίνησε το φθινόπωρο του 1973 για ανασκαφές στο τρίγωνο Αφάρ. Ήδη βρέθηκαν στοιχεία για ένα ανθρωποειδές που περπατούσε στα δύο πόδια.

Η αποστολή επέστρεψε την επόμενη περίοδο ανασκαφών, έπειτα από έναν χρόνο, στις 24 Νοεμβρίου του 1974. Ο Johanson με τους συνεργάτες του απομακρύνθηκαν πιο πέρα, κοντά στον ποταμό Awash, κοιτώντας πάντα για οστά. Ο Johanson αποφάσισε να ερευνήσει στο βάθος ενός μικρού ρέματος, παρότι ήδη προηγουμένως δύο εργάτες είχαν ελέγξει την περιοχή. Το έμπειρο μάτι του Johanson εντοπίζει ένα θραύσμα από ανθρώπινο βραχίονα. Δίπλα και άλλα θραύσματα, το ένα μετά το άλλο, εξωφθάλμως προερχόμενα από το ίδιο ανθρωποειδές. Το απόγευμα, όλα τα μέλη της αποστολής μαζεύτηκαν στο ρέμα και άρχισαν προσεχτική ανασκαφή και συλλογή θραυσμάτων που κράτησε τρεις εβδομάδες. Εκείνο το πρώτο βράδυ το γιορτάσανε τρελά στήνοντας μεγάλο πανηγύρι, με το κασετόφωνο να παίζει μουσική συνέχεια. Το τραγούδι που τους άρεσε και επαναλάμβαναν καθ' όλη τη διάρκεια της νύχτας, σε εκκωφαντική ένταση ήταν το "Lucy in the Sky with Diamonds" των Beatles, του 1967 [L(ucy) in the S(ky) with D(iamonds)]. Νάτη λοιπόν η Λούσυ!

Μέσα σε αυτές τις τρεις εβδομάδες, η ομάδα βρήκε πολλές εκατοντάδες τεμάχη ή θραύσματα, χωρίς επαναλήψεις βεβαιώνοντας ότι τα τεμάχη προέρχονται από το ίδιο άτομο. Υπολογίστηκε ότι 40% του ανθρωποειδούς σκελετού συνελέγη. Εκτιμήθηκε από τον Johanson ότι είναι θήλυ.

Η Λούσυ είχε 1,1 μ ύψος, υπολογίστηκε σε 29 κιλά και έμοιαζε κάπως με έναν χιμπατζή, εξ ου και ο μικρός εγκέφαλος της. Από τα χαρακτηριστικά των γλουτών βγήκε το συμπέρασμα ότι το εν λόγω ανθρωποειδές στεκόταν όρθιο και περπατούσε. Η ηλικία της Λούσυ προσδιορίστηκε με ραδιομετρικές μεθόδους.

Σήμερα η Λούσυ (αφού είχε κάνει μια βόλτα στο Cleveland) είναι αυστηρά περιορισμένη στα υπόγεια του μουσείου της Αντίς Αμπέμπα και εκτίθεται μόνο ένα πετυχημένο, πλαστικό ομοίωμα.

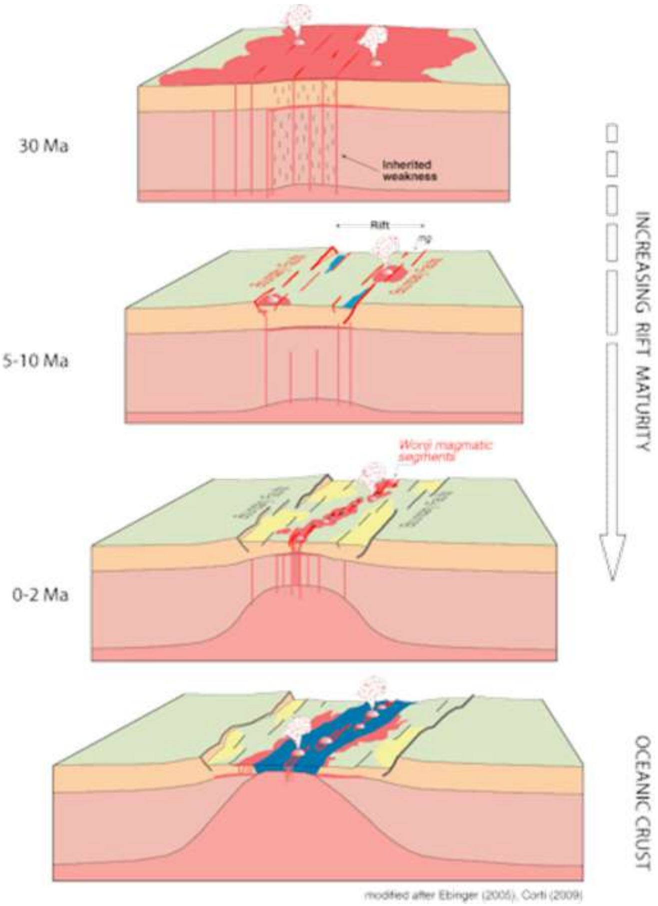
Side view of cast of Lucy in the Naturmuseum Senckenberg

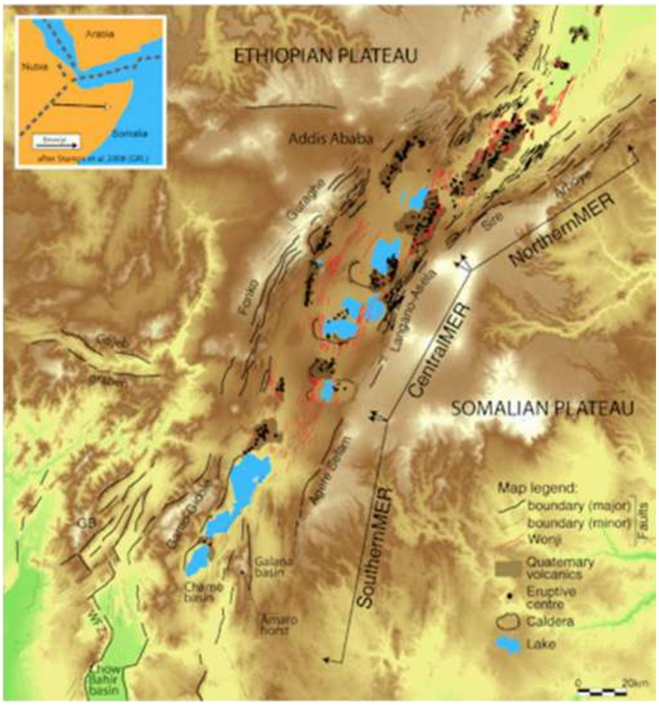
[1] Αργότερα βρέθηκαν λίγο παλιότερα ευρήματα αυστραλοπιθήκων στα ιδία χρονικά κι περιβαλλοντικά πλαίσια

Και λίγη Γεωλογία

Από τα ανοίγματα του φλοιού έβγαινε και η κατάσταση παραμένει ενεργή, λάβα. Αυτή δημιουργεί μεγάλα πλατώ σκεπάζοντας τους όποιους σχηματισμούς και ιζήματα κάλυπταν την τότε επιφάνεια.

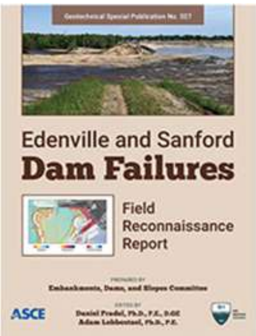
Για τα φράγματα μια τέτοια κατάσταση είναι επικίνδυνη γιατί ενώ τα ηφαιστειακά πετρώματα είναι γενικώς ικανά για τη θεμελίωση του **φράγματος**, τα κρυμμένα ιζήματα, αν είναι ασθενή και ευδιαύρωτα, μπορούν να δημιουργήσουν κινδύνους αστάθειας ή διαρροών από το έργο. Η έρευνα λοιπόν της μελέτης πρέπει να είναι προσανατολισμένη για τέτοιες αναζητήσεις.





Η **Πλατεία Αβησσυνίας** στην Αθήνα βρίσκεται στο ιστορικό τρίγωνο της παλαιάς πόλης. Η ονομασία της προέρχεται από την παλαιά ονομασία της Αιθιοπίας, Αβησσυνία, πιθανώς λόγω των Αιθιόπων που παλιότερα κατοικούσαν στη περιοχή αυτή.

ΝΕΕΣ ΕΚΔΟΣΕΙΣ ΣΤΙΣ ΓΕΩΤΕΧΝΙΚΕΣ ΕΠΙΣΤΗΜΕΣ



Edenville and Sanford Dam Failures: Field Reconnaissance Report

Edited by Daniel Pradel and Adam Lobbestael

Prepared by the Embankments, Dams, and Slopes Committee of the Geo-Institute of ASCE.

Following heavy rain over 2 days, the Edenville Dam experienced a slope instability on May 19, 2020 and failed catastrophically. Waters released by the breach of the Edenville Dam overwhelmed the Sanford Dam which was overtopped and failed on the morning of May 20, 2020 resulting in the evacuation of 11,000 people in the surrounding areas of Midland, Michigan, and along the Tittabawassee and Tobacco rivers.

Edenville and Sanford Dam Failures: Field Reconnaissance Report, GSP 327, presents the results of on-ground and aerial assessments that took place in the weeks following the failures.

The team employed aerial reconnaissance using optical, thermal, and LiDAR sensors; geophysical testing including seismic surveys and electrical resistivity surveys; geological reconnaissance to assess the nature of the geological materials; geotechnical sampling and laboratory testing including, moisture, density, grain size distribution, shear strength, and permeability testing; post-failure condition assessments; and reviewed historical documents and pre-failure LiDAR and satellite data.

This Geotechnical Special Publication focuses on the application of multi-sensor techniques to collect perishable data immediately after a disaster. It illustrates a range of site characterization technologies and extensive data analysis that will be of interest to practitioners, researchers, and community stakeholders in areas where old earth dams are nearing the end of their design life.

(American Society of Civil Engineers, 2021)

Shafts - Definitions and Classifications

Working Group 23

The ITA general Assembly approved the proposal for establishing Working Group 23 on «Design and Construction of Shafts» in May 2019 at the World Tunnelling Congress in Naples.

Following the first WG 23 meeting in Naples, the need for defining common terms was raised and it was decided to prepare a document to explain and develop the correct terminology and nomenclature for shaft design and construction.

It was also discussed that suitable classifications for shafts based on their geometry, application, ground conditions, and construction methods was needed for a more uniform understanding of design and construction implications.

This document is prepared in response to the above mentioned needs and provides common definitions for relevant terms in addition to introducing different types of classification systems for shafts that can be implemented during design and construction of these structures.

The document contains contributions of various individuals. Work has been coordinated by Siamak Hashemi (Animateur of WG 23) and Jamal Rostami. Tarcisio Celestino was the Tutor of WG 23.

Download document 026_2021_WG23_Shafts – definitions and classifications.pdf

(ITA Report, WG Publications, 2021)

Guidelines on Services of Machinery for Mechanized Tunnel Excavation

ITAtech Guidelines on Services of Machinery for Mechanized Tunnel Excavation

ITAtech Activity Group Excavation

The acquisition and the utilization of a Tunnel Boring Machine is a long process passing through a variety of steps and activities that can last several years in total from TBM design to final tunnel breakthrough. The different activities include design, manufacturing, shop assembly, transport, site assembly, disassembly, maybe reassembly, operational assistance, maintenance & repair, spare parts delivery and general technical assistance. Many of these activities involve Project Owner, Equipment (TBM) manufacturer, Equipment (TBM) user (Contractor) and Equipment (TBM) service provider as well as other specific suppliers. However, there is a clear line separating this long process in two distinct phases: exworks delivery will determine the end of the TBM manufacturing phase and the start of TBM Services phase. TBM Services are preferably provided by the TBM manufacturer but can also be provided by the TBM user itself or other qualified organizations (other TBM service provider). The purpose of this report is to provide guidance for project owners, designers, TBM users, TBM manufacturers and TBM Service providers when specifying requirements for TBM Services.

This guideline creates a common language in terms of TBM Services, listing all potential activities that must be scheduled as well as their ideal timing sequence along a tunnelling project. The correct understanding of TBM Services at the start of the project will help project owners, designers and TBM users realize correct planning of the works, evaluating the capacity to cover all activities and eventually take the decision to selfperform or outsource, as the case may be. Correct planning of the works will minimize both technical and commercial risks for the project, ensuring good coordination between planned activities and budgets and actual work performed. This report does not cover TBM refurbishment which in some cases may be considered a TBM Service activity. Guidance for this is given in ITAtech Report No 5-V2 "Guidelines on rebuilds of machinery for mechanized tunnel excavation".

Download document T012_2021_Guidelines On Services Of Machinery for Mechanized Tunnel Excavation_P.pdf

(ITAtech Publications, 2021)

Contractual framework checklist for subsurface construction contracts

Working Group 3

This 2nd edition of the Contractual Framework Checklist builds upon the 1st edition by identifying and clarifying key contractual practice subject areas that ITA believes are fundamental for the success of subsurface construction projects independently of the form of contract and risk apportionment used. This 2nd edition also endorses third party documents that ITA considers to have special subject matter or geographic significance and will further assist formulation of contractual practices for improved project performance.

ITA believes most existing standard forms of construction guidelines and contracts could deal better with the variabilities inherent in subsurface environments, and the impact of those variabilities when an Employer seeks to have an underground facility constructed in this variable environment. Application of this Contractual Framework Checklist will help all parties achieve the ultimate objectives of on-time, on-budget and fitness for purpose delivery of the subsurface (below the surface of the earth, be it water or land) infrastructure.

Download document ITA REPORT #25.pdf

(ITA Report, 2021)

ΗΛΕΚΤΡΟΝΙΚΑ ΠΕΡΙΟΔΙΚΑ

International Journal of Geoengineering Case Histories

An official journal of the International Society for Soil Mechanics and Geotechnical Engineering

Volume 6, Issue #3, https://www.geocasehistoriesjournal.org/pub/issue/view/49

40 Years of Full Scale Infrastructure Testing at a National Geotechnical Experimentation Site: Clay Site Jean-Louis BRIAUD

40 Years of Full Scale Infrastructure Testing at a National Geotechnical Experimentation Site: Sand Site Jean-Louis BRIAUD

ISRM Newsletter No. 55 - September 2021
https://isrm.net/newsletter

Κυκλοφόρησε το Τεύχος Αρ. 55, Σεπτεμβρίου 2021 με τα ακόλουθα περιεχόμενα:

- Presidential election for the 2023-2027 term of office
- New ISRM Fellows inducted during the ISRM International Symposium - Eurock2021
- 35th ISRM online lecture by Dr Christine Detournay
- New ISRM website launched in August
- ISRM International Symposium LARMS2022 - call for papers
- ARMS11, Beijing, China, 21-25 October, the 2021 ISRM Asian Regional Symposium
- Eurock2022, Helsinki, Finland, 12-15 September - call for papers
- ISRM 2020 and 2021 Awards given during the ISRM International Symposium - Eurock2021
- ISRM Rocha Medal 2023 - nominations to be received by 31 December 2021
- 2021 ISRM Latin American Lecture Tour: 27 September - 1 October
- Mongolian was added to the ISRM Glossary
- Video of the Suggested Method on Needle Penetration Test
- ISRM Sponsored Conferences

Κυκλοφόρησε το IGS Newsletter της International Geosynthetics Society με τα παρακάτω περιεχόμενα:

IGS NEWSLETTER – September 2021

Helping the world understand the appropriate value and use of geosynthetics

httpwww.geosyntheticssociety.org/newsletters

- IGS Opens Call to Host the 13th ICG 2026! READ MORE
- Out Now! Chapter Chat Summer 2021 READ MORE
- Book Now For IGS 'Big Four' Conferences READ MORE
- Chapter News - IGS Chile
  - IGS Chile Hosts First Members' Assembly READ MORE
  - Watch: Educate the Educators Invitation from IGS Chile READ MORE
- Sustainability eBook Now In Portuguese! READ MORE
- Upcoming Webinars - September 2021
  - The design of drainage geocomposites for long term applications, September 14, Presented by Eric Blond REGISTRATION INFORMATION
  - The Role of Geosynthetic Liners: Minimizing Leakage and Contaminant Impacts, September 15, Presented by R. Kerry Rowe REGISTRATION INFORMATION
  - Technical Forum #2 - Geosynthetics in Reinforcement Applications, September 15 (Brisbane time), Panelists include Richard Bathurst, Pietro Rimoldi, Ivan Puig Damians, Chris Lawson, and Mike Dobie REGISTRATION INFORMATION
  - Successfully specifying, performing and interpreting interface shear tests, September 22 (Brisbane time) and Repeat Session on September 30, Presented by Gary T. Torosian REGISTRATION INFORMATION
  - AASHTO Migration from the Simplified Method to the Stiffness Method for internal stability design of MSE walls, September 23, Presented by Richard Bathurst REGISTRATION INFORMATION
- Calendar of Events

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