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High-resolution 3D outcrop model-based characterization of shoreface sequence architectures on an uplifting interbasinal relay zone: the Late Quaternary Corinth Isthmus, Greece.

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Objectives and Scope

Beach and shoreface systems represent significant subsurface reservoir targets but there are few studies of their detailed stacking patterns in tectonically influenced settings. In active rift settings, shorefaces are likely to develop around interbasinal highs where accommodation is generated and destroyed episodically at a modest rate. Here we characterize the response of shallow marine sedimentary architectures to uplift and to high-frequency global sea-level changes within stacked post-glacial retrogradational and aggradational-progradational-degradational systems tracts exposed in the Corinth Canal, central Greece. We examine details of sequence stratigraphic architecture that may, for the first time, resolve millennial-scale fluctuations in the rate of relative sea-level rise during particular post-glacial transgressions. This study also provides opportunity to study the structural evolution of the Corinth Isthmus, which has acted as a tidal strait between the Gulf of Corinth and the Saronic Gulf. And correlation of the onshore stratigraphy to the offshore stratigraphy recently described from IODP Expedition 381 boreholes is now possible by exploiting key bounding surfaces and a variety of dating techniques.

Methods, Procedures, Process

The Corinth Isthmus is located on the eastern edge of the Gulf of Corinth, which has a high extensional tectonic strain rate. The Isthmus is an interbasinal high undergoing uplift, which has undergone deposition of lacustrine and marine to continental sediments, as exposed in cliffs up to ~80m high in the Corinth Canal. The artificial Corinth Canal passes through the Isthmus of Corinth and connects the Saronic Gulf with the Gulf of Corinth. Using georeferenced, textured 3D outcrop models built from point-clouds obtained from photogrammetric data and non-textured coloured triangulated meshes built from Lidar data, field-based sedimentary logging and facies analysis, we construct a higher resolution architecture of the exposed Late Quaternary beachface

to shoreface successions than was previously possible. It enables reconstruction of the range of palaeoenvironments that are represented in the ~ 3km-long NW part of the Canal's section.

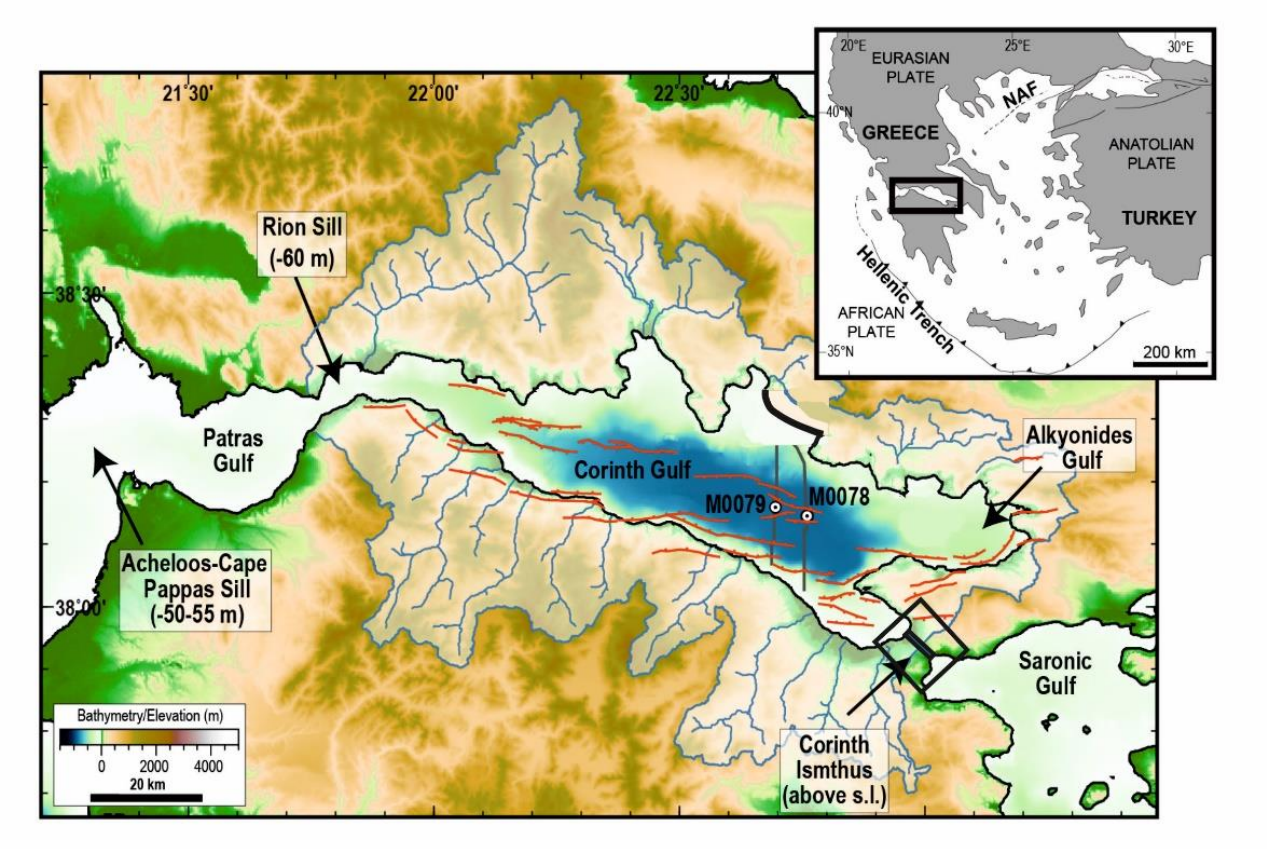

Figure 1: Location map of the Corinth Canal, central Greece modified after Gawthorpe et al (2022).

Recent excavation of the Canal walls has allowed repeated drone surveys to be carried out, from which the 3D models are built. Virtual Reality Geological Studio (VRGS) software is used to map key stratigraphic surfaces, including combined sequence boundaries and ravinement surfaces. Syn-depositional normal faults propagating though the sedimentary packages modify accommodation space for the incoming sediments and control the thickness variations in respective facies as mapped in the 3D models. These outcrop models can aid in a long-term to extend the limit of human timescale. U/Th dating is being carried out of in-situ stems of Cladocora caespitosa (coral) from 6 sites NW of a central horst block. Palaeomagnetic analysis is also underway of 21 marly samples through the vertical succession of the central horst block using alternating field treatment and thermal demagnetization for high resolution results. These dating technigues and sequence stratigraphic correlation with IODP Expedition 381 borehole

stratigraphies in the deep-water Corinth Rift axis allow construction of a new high resolution chronostratigraphic framework. Facies trends are used to determine relative sea-level changes within each transgressive-highstand cycle of ~104year duration. This study then allows us to reconstruct the evolution of the Corinth Canal sedimentary sequences in response to global sea-level changes and to the intrabasinal syn-sedimentary faults active in the interbasinal realy zone.

Results, Observations, Conclusions

A central horst block preserves stratigraphy back to ~800 ka since when the Isthmus has been a tidal strait during periods of relatively high sea-level. The Gulf of Corinth basin has undergone episodes of marine connection during global highstands but experienced isolated lacustrine conditions when disconnected across the Isthmus during global marine lowstands (e.g. Gawthorpe et al., 2022). In the Canal, NW-dipping faults towards the Gulf of Corinth and SE-dipping normal faults towards the Saronic Gulf control the position of the central horst block high and exhibit variably planer to listric and both horizontally- and vertically- segmented geometries. Syn-depositional movement on these locally affected relative sea-level on a small scale, influencing the facies trends and their thicknesses. The timing and growth history of the faults is constrained by the detailed stratigraphic framework.

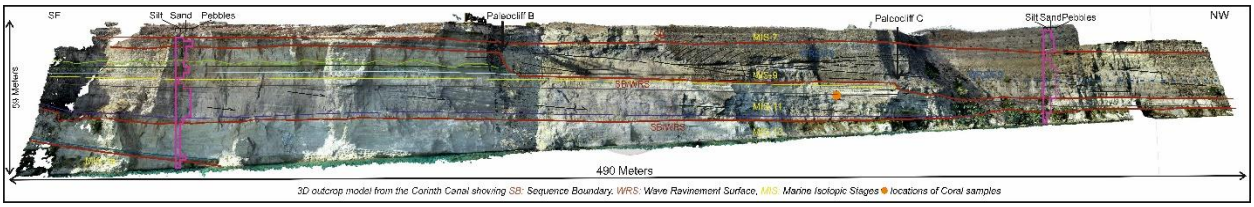

Figure 2: 3D outcrop model from NW side of the Corinth Canal showing different stratigraphic packages stacked above each other bounded by sequence boundaries combined with wave ravinement surfaces and surfaces of sub-aerial exposures).

The north-western Corinth Canal reveals the upper parts of 8 prominent transgressive-regressive cycles in the Quaternary coastal facies belt, which are bounded by surfaces recording both sub-aerial exposure and wave ravinement. Intervening shallow marine transgressive to highstand deposits are ascribed to the interglacial episodes of marine isotopic stages (MIS) 1, 5, 7a/c, 7e, 9, 11, 13 and 17 based upon our age model. Marine facies include distinctive peridotite clasts indicating that the major provenance was from a serpentinite-bearing ophiolite thrust sheet exposed in the basin margin to the north. Conglomeratic facies comprise normal- and reverse-graded, large to very large scale cross-bedded, matrix-supported and open framework clast-supported deposits with low-angle cross-sets and simple and complex dune architectures,

including meter-scale bar forms with alternating dips. These constitute the beachface facies association. Trough cross-bedded to laminated, sandy beds with conglomeratc interbeds which thin downdip, and including symmetric ripple forms with silt drapes are typical of the shoreface facies association. Lower shoreface to offshore facies include meter-amplitude hummocky cross-stratified beds and moderately to highly bioturbated silts with abundant macrofossils including in-situ branched corals. Oolitic sands from a shoal, wave-influenced environment locally form calc-arenites in the younger stratigraphic section. Waves and tides effect the sediment geometries and have formed wave and/or tidal ravinement surfaces on sequence boundaries. Successive sequences offlap basinwards, suggesting an overall forced regression across the period of deposition. Individual transgressive surfaces, such as that correlated to the MIS 10-9 deglacial transition (a period of ~10kyr), include a) incised channels with fluvial infill, b) laterally extensive wave-cut platforms, and c) palaeocliffs that mark episodes of relative stillstand or falling sea-level and enhanced wave erosion during the overall transgression. Fining-up grain-size trends and deepening-up facies trends occur above ravinement surfaces and are interpreted as transgressive packages. Secondary unconformities within these packages again imply temporary pauses or reversals of the transgressive trend. These may relate to a) millennial time-scale global sea-level falls within the overall deglacial transgression, as has been implied by marine isotope studies, or b) relative sea-level falls produced by local faulting, or c) scouring by marine currents within the narrow interbasinal seaway. The detailed architecture of the sequence boundaries and transgressive systems tracts, including across faults, will be assessed to test whether the ravinement did indeed occur during transgressions and to distinguish the above scenarios.

Significance/Novelty:

This study demonstrates the added value provided by high-resolution 3D stratigraphic models combined with high resolution age models in resolving complex palaeoenvironmental problems. We propose that detailed geological observations support the occurrence of short-term fluctuations in glacio-eustatic sea-level during Late Quaternary deglacials that were previously only suggested by marine oxygen isotope records. The 3D models also provide quantitative descriptions of reservoir analogue architectures that can be used to aid prediction of subsurface reservoir architectures in similar tectonic settings.

Acknowledgements

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References

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