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Editorial: Sedimentary System Response to External Forcings: A Process-Based Perspective

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Editorial on the Research Topic

Sedimentary System Response to External Forcings: A Process-Based Perspective

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Improving our understanding of how the Earth system responds to change is a critical goal in geoscience. Using the sedimentary record to investigate ancient processes, events, and interactions has contributed to our increasing knowledge of Earth system functioning, yet there is still much to discover. Tectonic activity, climatic conditions and fluctuations, and sea-level change can have substantial impacts on sediment generation, delivery, and accumulation, all of which, in turn, influence the nature of the resulting stratigraphic record. Additionally, the interacting effects of these multiple forcings are complex and, in many cases, compounded by the influence of self-organized dynamics associated with sediment transport processes. Thus, to be able to extract accurate and meaningful information from sedimentary archives we must continue to examine how external (and internal) controls are (or are not) encoded into stratigraphy. All the contributions in this Research Topic touch on the notion of multiple forcings, but span a variety of sedimentary system types, depositional environments, geologic age, tectonic setting, climatic conditions, spatial and temporal scales, and more. Additionally, this Research Topic features a diverse range of methodology and data types, including outcrop characterization, detrital geo- and thermochronology, subsurface mapping, numerical and physical experiments, and other approaches. The 13 contributions to this Research Topic are briefly summarized below and organized in source-to-sink order with upland sedimentary systems (fluvial, alluvial, eolian) listed first, followed by coastal and shelf margin, and ending with the deep sea.

Capaldi et al. employ detrital zircon U-Pb geochronology and sediment mixing models of modern sediments from the continental Andean foreland to show the impact of climate-modulated processes, such as eolian transport and reworking, on sediment provenance signals. Implications for this work bear on how tectonic signals, local storage, and recycling of synorogenic river sediment are reflected in sedimentary archives.

Finzel combines new and pre-existing data to compile an extensive detrital zircon U-Pb geochronologic dataset from modern rivers of the Mesozoic-Cenozoic igneous belts across mountainous regions in south-central Alaska (United States). Finzel uses a recently developed unmixing approach to compare these data to an extensive detrital zircon U-Pb dataset from Lower Cretaceous to Pliocene strata in the forearc basin, in order to investigate the variations in long-term provenance and sediment dispersal patterns in the basin in response to tectonic events. Results reveal a previously undetected sediment recycling source during the Late Cretaceous and Oligocene, linked to specific plate margin events. The unified approach of extensive modern river sampling, comprehensive basin strata characterization and mixture modeling is a valuable approach for partitioning of widespread and pervasive ages in sediment source terranes with long-lived magmatic histories, and for resolving sedimentary recycling into a basin.

Meek et al. analyze the stratigraphic architecture of two well-exposed ancient alluvial fans in the western United States (Eocene Richards Mountain Conglomerate and Cretaceous Echo Canyon Conglomerate), deposited under relatively similar climate and tectonic regimes, by employing uncrewed aerial vehicle-based photogrammetric models. The authors use a seven-fold hierarchy of bounding surfaces to describe alluvial fan architecture to examine the relative dominance of autogenic and/or allogenic factors. They show that the architectural style of the two alluvial systems is significantly different and link this difference to the mobility of active channels within the fans, attributed to a more seasonal climate, with less vegetation, where increased sediment flux and flood events would have destabilized channels and thus enhanced lateral migration. These results imply that a specific scale of stratigraphic architecture of ancient alluvial fans can provide insight into allogenic controls related to paleoclimate. They also suggest that in regions where anthropogenically induced climate change results in more variable precipitation, alluvial fans may show decreased channel stability, and consequently imply a greater risk to human activity and development on alluvial fans.

Leonard et al. carried out a detailed provenance and sedimentologic study of Oligocene-Miocene foreland basin infill in the Magallanes-Austral Basin to investigate relationships between tectonic activity in sediment source areas and eustatic sea-level. By comparing modal compositions of sandstone and conglomerate with detrital zircon U-Pb geochronology, they suggest a major shift in source area between 27 and 24 Ma that is consistent with rejuvenation of arc magmatism and hinterland fold-and-thrust belt activity. Notably, this provenance change predates a basin margin change in depositional environment from marginal marine to fluvial sedimentation, but the ~2 Myr erosional unconformity beneath the tectonically generated coarse-grained fluvial deposits may be at least partially influenced by a latest Oligocene global regression across this time interval.

Bauer et al. investigate the influence of inherited depositional topography on the evolution of constructional shelf-slope systems, the position of shelf edge zones, and development of phases of coarse-grained sediment delivery to deep water. They combine new outcrop data with published studies of the Cretaceous Tres Pasos and Dorotea Formations, southern Chile, to show that the position and character of abrupt changes in slope from preceding depositional phases impart a significant influence on the position of subsequent shelf-edge zones. With these results, Bauer et al. suggest that the allogenic-autogenic dichotomy is not always so clear, especially in the context of depositional topographic influence that persists through time.

Abatan and Weislogel reconstruct the paleohydrology of Pennsylvanian (~310 Ma) river channels via outcrop characterization coupled with machine learning-assisted methods to examine controls on resulting fluvial stratigraphic architecture. Channel body geometry, sedimentary structures, and grain-size distributions were used to estimate paleoslope and flow velocity. Their results suggest a change from a humid ever-wet climatic regime to a semi-arid, seasonally wet climate during deposition of these fluvial systems and they also discuss the potential effects of tectonic subsidence and sea-level change.

Sømme et al. investigate depositional system response to a short-lived (~0.2 Myr) climatic perturbation superimposed on long-term (~10 Myr) tectonic controls to better understand how these different controls are expressed in the stratigraphic record. They use regional 3D seismic-reflection data combined with borehole and biostratigraphic information to map Paleogene depositional systems and reconstruct sediment supply along the Norwegian margin. They show that the relatively short-lived Paleocene-Eocene Thermal Maximum does not correlate with a discrete peak in sediment supply as it does in depositional systems elsewhere, but may be expressed as a downlap surface recording a base-level rise. Sømme et al. use their results to discuss how tectonic processes and along-strike variability of these multiple interacting controls can potentially be discriminated in stratigraphy.

Straub uses physical experiments to explore how sea-level cycles of varying magnitude and periodicity influence the architecture of linked delta-continental slope sedimentary systems. Results of these state-of-the-art experiments show that, on average, sediment delivery to the slope is promoted during sea-level lowstands. However, smaller magnitude and higher-frequency sea-level cycles lead to greater stochasticity and, therefore, a less predictable response.

Pasquier et al. use strontium isotope geochemistry of Pleistocene deposits in offshore Gulf of Lion, western Mediterranean Sea, to link the proportion of detrital carbonate rocks in the catchment to considerations of source-to-sink flux, which commonly only emphasizes siliciclastic accumulation. Their results indicate a relatively high export of detrital carbonates from the catchment during both glacial and interglacial conditions and suggest that, in analogous systems in the geologic past, detrital carbonate could influence bulk carbonate strontium isotope ratios and their associated chemostratigraphic application.

Ciarletta et al. investigate the dynamics of retreating barrier island systems in the context of sea-level change using a numerical modeling approach. Specifically, they hypothesize that deposits that result from intrinsic (autogenic) processes are linked to higher rates of relative sea-level rise, which could disrupt or mask external signals. Their results suggest that barrier island response to a sea-level pulse is controlled by the magnitude and timing of that pulse, as well as by interactions of shoreface with overwash processes. Additionally, they show that millennial-scale periodicity leads to barrier island systems becoming vulnerable to drowning, even with relatively low rates of relative sea-level rise.

Wei et al. studies two submarine canyon systems in the Inner California Borderlands, offshore Southern California, to investigate how tectonics, shelf width, gradient, and autogenic processes influence turbidite sedimentation. Based on new geophysical imaging, piston and gravity cores, and radiocarbon dating of foraminifera, these authors suggest that Dana Point

Canyon remained active during the most recent sea-level lowstand, transgression, and highstand. In contrast, elsewhere along the shelf, sediment delivery to the San Onofre North and South canyons may have been inhibited by structural growth along the right-lateral Newport Inglewood/Rose Canyon Fault after 8 ka.

Hawie et al. addresses the importance of grain size and discharge as independent controls on submarine fan architecture. They use stratigraphic forward models with variable diffusion coefficients to examine the sensitivity to a range of grain sizes and sediment discharges on submarine fan depositional response. Increasing discharge leads to thicker packages with fewer channel avulsions, coarse-grained sediment build-up at the mouth of the feeder channel, and bypass of fine-grained material. Variable grain-size input experiments show that fine grain sizes result in further basinward transport whereas coarser loads develop compensational stacking.

Hülscher et al. test how four well-known tectonic/erosional events in the European Alps—exhumation of the Tauern Window, Lepontine Dome, visco-elastic relaxation of the European plate, and unroofing and redeposition of the Augenstein Formation—propagated through and into different compartments of the sediment-routing system and how they are recorded in a submarine channel-overbank system. They evaluate the Oligocene-Miocene stratigraphy, biostratigraphy, and chemostratigraphy, along with 3D seismic-reflection data, in the Upper Austrian Molasse Basin and calculate timescale-invariant, spatially averaged sediment-accumulation rates for different time periods and different segments in the basin. Results and interpretations highlight the stratigraphic complexity of a gravity-flow dominated deep-marine channel system and its sedimentological record of these important tectonic/erosional events.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.