High-resolution optical and acoustic 3D seafloor reconstructions from robot and diver-based surveys

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Robust simultaneous localization and mapping (SLAM) techniques have become standard techniques for navigation of robotic platforms over the last decade. SLAM allows autonomous robots to use environmental information to improve their navigation and map estimates. A key aspect of SLAM is that it maintains a representation of the uncertainty of the map and vehicle trajectory. This enables a principled (and automatic) approach to enforcing consistency in maps when revisiting an area (such as when ‘closing a loop’ or when using overlapping tracklines). In essence, SLAM allows multiple views of the same feature to be mapped to the same location, reducing map errors such as drift and repeated structures. In the context of underwater surveys, SLAM enables properly instrumented robots to collect data and generate geo-referenced, self-consistent maps. In practice, these algorithms fuse multiple sources of navigation data such as surface GPS, acoustic positioning, Doppler velocity log (DVL), inertial measurement units (IMU) and depth, with environmental observations from cameras and sonar.

This paper presents a brief overview of the capabilities that the marine robotics group at the Australian Centre for Field Robotics (ACFR) has developed in terms of improved high resolution optical and acoustic mapping, automated interpretation and visualization. We then show how some of these technologies have been applied to SCUBA-based surveys that result in high-resolution, geo-referenced 3D mosaics without requiring robotic platforms.

We present results from the autonomous underwater vehicle (AUV) Sirius and a diver-held stereo camera rig. Both natural and man-made structures are reconstructed, with techniques that enable large-scale composite views that preserve 3D structure. Preliminary results for monitoring applications are also presented, discussing the ability to revisit an area and detect changes in time.

The range of capabilities developed at the ACFR can potentially assist underwater archaeology in a broad range of applications including the automatic generation of 3D reconstructions of large underwater sites, effective visualization and interaction of archaeologists and general public with these reconstructions, and potentially automated monitoring for degradation or disturbance of archaeological sites.

Tracing the ancient tectonic processes by coarse-grained, mass-flow deposits: the Western Carpathian Mesozoic – Palaeogene case history

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Tectonically generated mass-flow deposits, such as terrigenous tectonosedimentary breccias and flysch-related conglomerates, form stratiform bodies of coarse-grained, poorly sorted resediments inserted within more fine-grained, usually deep-marine clastic and/or pelagic sediments. They were emplaced by some gravity-driven mechanism and include various block-in-matrix type sediments named as olistostromes, pebbly mudstones, scarp breccias, wildflysch, etc. The mass-flow deposits may occur in a range of environments and tectonic settings – either extensional, or contractional. The former are designated as the synrift, the latter as the synorogenic conglomerates. Both provide very useful palaeotectonic information, since their composition and stratigraphic position often allow an exact timing of distinct orogen-scale tectonic events. We present a case study of tectonosedimentary conglomerates from the Central Western Carpathians (CWC) and Pieniny Klippen Belt (PKB). They are interpreted as unique tracers of Mesozoic–Palaeogene tectonic history of the Carpathian orogen.

Extensional tectonic regimes are mostly associated with rifting events, when newly formed basins are quickly subsiding and filled with terrigenous clastic material derived from uplifted rift shoulders. The extension-related synrift breccias were exclusively fed by local, normal fault-related sources and their composition reflects ongoing denudation of the source areas. Deposition may cover a considerable time span (tens of Myrs), on condition that rifting occurred in several pulses.

The first Mesozoic synrift breccias in the Western Carpathians are known from the Middle Triassic. They were related to the late Anisian rifting and breakup of the Meliata Ocean. Early–Middle Jurassic extensional phases are recorded by halfgraben formation and comparatively widespread synrift clastics, such as olistolite-bearing scarp breccias in the Tatric, Fatric and Oravic domains. Aprons of proximal breccias are interfingering basinwards with hemipelagic or sandy turbidite-dominated sediments. Their composition reveals stepwise exhumation and erosion of the source areas and they are interpreted as activations of rift shoulders generated by rifting and breakup events of the South Penninic-Vahic Ocean. The lowermost Cretaceous breccias occur in the Tatric and Fatric, but mainly in the Oravic superunit, where they record the North Penninic-Magura oceanic breakup. Still younger, Barremian–Aptian olistostromes occur in the ridge-related Tatric and Fatric units.

Synorogenic sedimentary complexes related to compressional tectonic regimes terminate the sedimentary successions of inverted basins. In the course of ongoing deformation, they are often destroyed shortly after origin and their material can be recycled several times. Synorogenic breccias/conglomerates contain a variable material derived from wide orogenic zones characterized by a complex geological structure. The contraction-related mass-flows exhibit a distinct coarsening and thickening upward trend. Unsorted material eroded from the overriding sheet and well-rounded and sorted material derived from distant subaerial sources and/or recycled from older conglomerates, are often mixed together. Their deposition seldomly exceeded a few Myrs; thus their sedimentary age narrowly constrains the timing of related thrusting events.

Middle–Upper Jurassic olistostromes of the Meliatic and Silicic units represent the synorogenic breccias formed in response to the Meliata Ocean closing. In the paleogeographically more northern areas, the first such sediments appeared in the Aptian–Early Albian of the Fatric domain where they record the incipient inversion of this large intracontinental rift basin. Subsequently, the thick prisms of mid-Cretaceous "exotic" conglomerates of the Tatric-Fatric units (incl. the PKB Klape unit) were deposited. Senonian–Palaeogene synorogenic breccias are particularly frequent in the front of the CWC orogenic wedge where they originated in response to subduction of the Penninic oceanic zones (Váh and Magura Oceans) and collision of their former continental margins. In the PKB, the deep-marine conglomerate bodies with olistoliths were formed in relation to thrusting events of the Oravic units. Their composition directly reflects lithology of the overriding thrust sheets. It has been found that numerous "klippen" are in fact olistoliths – a feature often overlooked until now.

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