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Stratigraphic Architecture of Deepwater Channels in Outcrop, Tres Pasos Formation, Chile: Sub-seismic Scale Insight into Channel Stacking Behavior at the Base of a High-Relief Basin Margin Slope

Ryan V. Macauley
Department of Geoscience, University of Calgary, Calgary, Alberta, Canada
rvmacaul@ucalgary.ca
and
Stephen M. Hubbard
Department of Geoscience, University of Calgary, Calgary, Alberta, Canada

Abstract

Substantial hydrocarbon discoveries have been made in deep-water slope channel deposits along continental margins worldwide. Development of these resources has fostered inquiry into the reservoir properties of associated sedimentary bodies and encouraged investigation into depositional processes responsible for transporting coarse grained sediments into deep-water. Seismic reflection imaging has been the primary means for studying deep-water sedimentary systems in the subsurface, producing vivid 3D perspectives of slope channel deposits as they evolve through time. Despite the high quality of these datasets, sedimentological detail irresolvable in seismic data sets, is crucial to identifying hydrocarbon reservoir heterogeneities necessary for executing effective resource development plans. The exceptionally preserved strata of the Cretaceous Tres Pasos Formation, southern Chile, represents an important means for acquiring this bed-scale detail and provides insight into channel stacking patterns at the highest resolution possible. Importantly, the three-dimensionally exposed channel deposits are associated with seismic-scale stratal architecture, making the link from outcrop to subsurface realistic.

The mudstone- and siltstone-dominated strata of the Cretaceous Tres Pasos Formation preserves a prograding high-relief slope system, characterized by > 800 m of bathymetric relief. An outcropping sandstone-rich slope channel deposit 2.5 km long, and ~130 m thick located at the base of this slope is the focus of this study. The architectural detail of the outcrop was analyzed, aided by the numerous gullies that crosscut the outcrop at high angles and provide excellent 3D exposures of channel geometries (Fig. 1). The framework of this study is provided by a database consisting of 1607 m of measured stratigraphic section, numerous photomosaics, hundreds of paleoflow indicators and thousands of high-resolution GPS

measurements. This data was used to map stratigraphic surfaces and project mappable sedimentary bodies into three dimensions (Fig. 2).

The 130 m thick succession studied comprises eighteen channel elements between 6-15 m thick, which stack vertically or slightly offset from one another (Fig. 2). These elements can be grouped into three channel complexes 25-70 m thick (Fig. 1 & 2), demarcated by: (1) basal siltstone-dominated deposits that persist across the entire outcrop belt (Fig. 1); and (2) significant shifts in channel element stacking patterns (Fig. 2B). Internally, channel elements consist of stacked sedimentation units, attributed to deposition from high-concentration turbidity currents. Channel fills are characterized by a rapid transition (commonly < 20 m) from high net:gross axial facies, to interbedded, low net:gross marginal facies.

The overall stratigraphic architecture records punctuated periods of channel incision and subsequent sedimentary bypass followed by depositional stages where channels are in-filled by collapsing, turbidity-currents. When the architecture of the Tres Pasos Formation is compared in cross-section to analogous deposits imaged in seismic reflection datasets, significant similarities are apparent. An observed transition from weakly confined, unidirectional lateral stacking to vertical aggradation is common to both the Tres Pasos Formation and numerous subsurface analogs. The stacked channel elements from this study provide a level of resolution unparalleled in seismic data sets, providing cm-scale measurements that could be used in reservoir models.

The fine-grained units that bound the channels in the Tres Pasos Formation are primarily covered and unrecognized across the outcrop belt; however, it is reasonable to suggest by analogy to seismically defined channel systems that this confinement is provided by inner levee deposits.

Reference

Hubbard, S.M., Fildani, A., Romans B.W., Covault, J.A., McHargue T.R., 2010, High-relief slope clinoform development: Insights from outcrop, Magallanes Basin, Chile: Journal of Sedimentary Research, v. 80, p. 357 – 375.

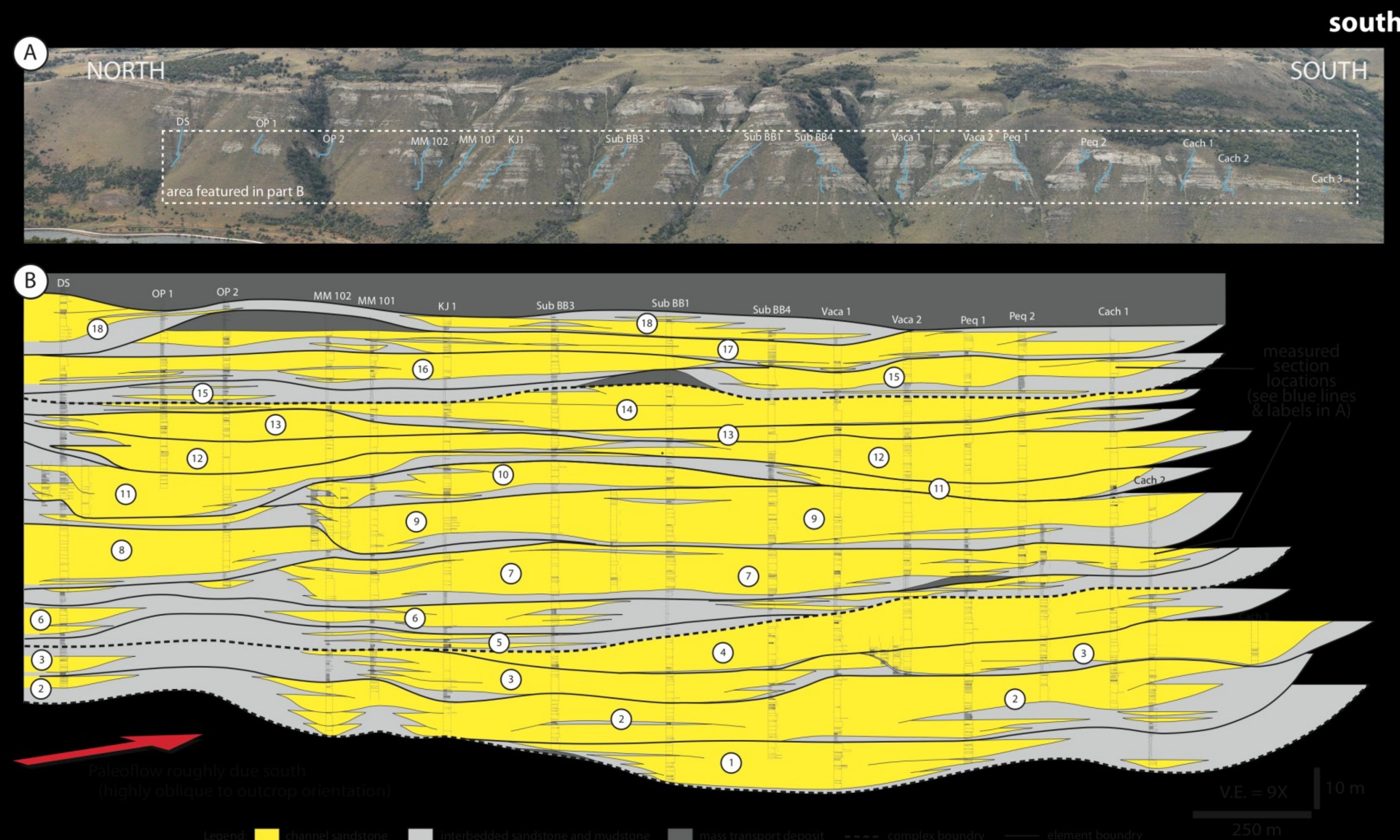

Fig. 1. (A) Photomosaic of the study area stratigraphy. Blue lines identify the locations of each of the measured sections recorded across the study area. The 1607 m of detailed (cm-scale) measured section provides the framework for this work. (B) Stratigraphic cross-section showing eighteen outcroping slope channels preserved in the Tres Pasos Formation. The 130 m thick sedimentary package is divisible into three channel complexes. These divisions (shown by dashed lines), demarcated by wide-spread mudstone-dominated units, are present across the entire outcrop belt. In general, the northeast–southwest trending cross-section is oriented highly oblique to paleoflow, which was roughly southward. Quaternary erosion of the slope channel deposits cut gullies near perpendicular to paleoflow, providing local 3D perspectives. This cross-section attempts to capture the three-dimensional details provided by these perspectives on a flat panel. Widespread bypass drape deposits mantle channel bases and serve to partition sandstone channel bodies within the stratal package. After characterizing the entire length of the outcrop belt, it is evident that these drapes are not always laterally persistent.

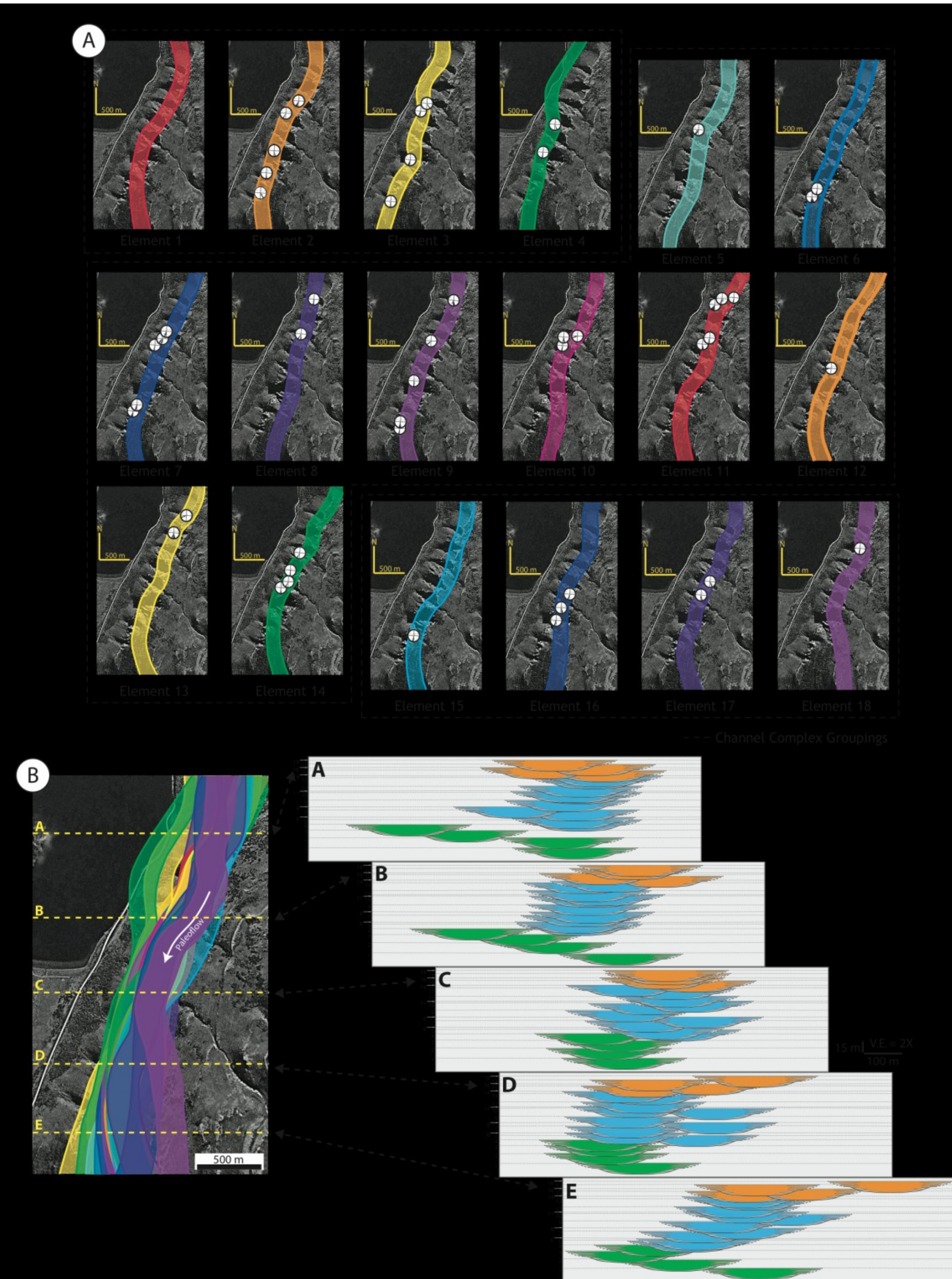

Fig. 2. (A) Channel stacking patterns were examined by reconstructing the plan view morphology of the eighteen elements identified in the slope channel complex set (See Fig. 1). Interpretation is grounded in fieldmapping using high-resolution GPS, hundreds of paleoflow measurements recorded at different stratigraphic levels, and the regional context outlined in Hubbard et al. 2010. Dashed lines group channel elements into the three channel complexes interpreted in this study. (B) Composite figure showing reconstructed channel elements (See Fig. 2A) stacked vertically or slightly offset of one another. Paleoflow was roughly southward. A series of five depositional-strike-oriented cross-sections were constructed with the most proximal section presented in A and the distal most section is E. All channel elements, 1-18, correspond to those shown in the detailed cross-section (Fig. 1) and the plan view reconstruction (Fig.2A). Channel elements with common stacking patterns are separated into channel complexes and differentiated by colour. Note the variation in stacking patterns expressed over the 2.5 km outcrop belt.