Characterizing Depositional Elements of a Deep Water Channel Complex using Quantitative Metrics, Tres Pasos Formation, Southern Chile

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Summary

The Cretaceous Tres Pasos Formation of the Magallanes foreland basin, southern Chile, consists largely of mudstone- and siltstone-dominated strata associated with a prograding high-relief slope system. This study focuses on coarse clastic base-of-slope deposits, interpreted to represent a deep-water turbidite channel complex-set as described by Hubbard et al (2010).

Sedimentological metrics provide a quantitative method for utilizing 1-D data (ie, measured section, core) in order to extrapolate channel dimensions and associated facies distribution (McHargue et al, 2010). The goal of the work is improved predictive insight into complex stratigraphic correlations in the subsurface through examination of well-constrained slope channel deposits in outcrop. The outcrop belt examined is 2.5 km wide by 130 m high, from which the deep-water facies and architectural detail necessary to build a metrics database was acquired. The robust dataset derives rock properties (metrics) from 1607 m of measured section and field mapped architectural detail such as channel margins. Practically, by analogy to characteristics of this database, a development geologist can determine what intra-channel sub-environment (axis, off axis, margin; Figure 1) has been intersected by a wellbore. The metrics tabulated from the slope channel outcrop in Chile are applicable to analogous units in the subsurface in numerous basins worldwide (e.g., West Africa, South China Sea), providing high-resolution (sub-seismic) insight into reservoir compartmentalization and connectivity.

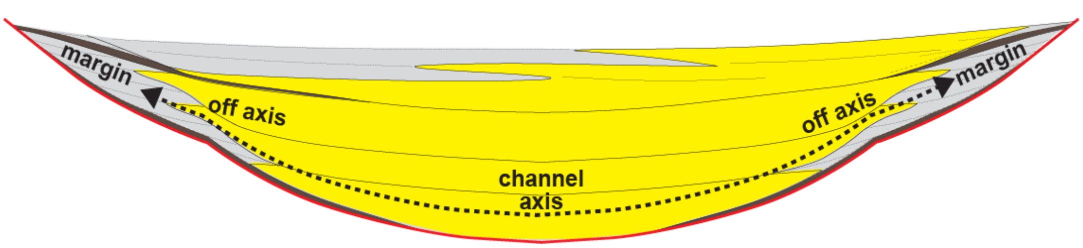

Figure 1- Idealized cross section of a channel element, typical of the Tres Pasos Formation. The channel elements are generally up to 15 m thick to 300 m wide.

Facies Associations

Four main facies are defined in this study:

Facies A- Amalgamated sandstone, erosive bases, abundant mudstone clast conglomerate, coarse-grained basal lags, limited traction structures.

Facies B- Amalgamated sandstone, common flat contacts between beds, lesser mudstone clast conglomerate, abundant traction structures.

Facies C- Non-amalgamated sandstone, preserved silt and mud between beds, >75% sandstone.

Facies D- Interbedded non-amalgamated sandstone and mudstone, <75% sandstone.

Method

Figure 2 demonstrates the delineation of properties (metrics) to a small portion of a measured section within a single channel element. The typical workflow is as follows: 1. As the section is measured, individual sedimentation units (deposits attributed to a single gravity flow event) are delineated and thickness recorded. 2. Each bed-set has a facies association applied to it based on the aforementioned criteria. 3. The contact between beds is determined to be amalgamated or non-amalgamated. 4. Upon completion of the entire section, element scale contacts between channels are demarcated. 5. For each channel element, the maximum thickness of amalgamated sandstone is determined along with the overall thickness of the element.

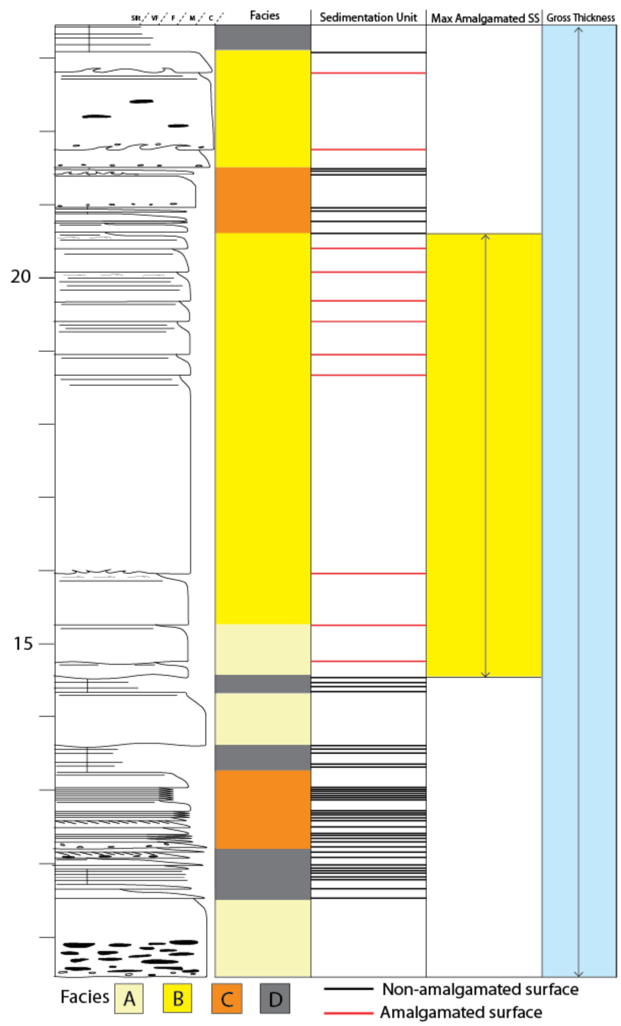

Figure 2- Demonstration of properties gleaned from a measured section. Critical rock property information includes facies association, nature of sedimentation unit contact, maximum thickness of amalgamated sandstone, and total element thickness.

Discussion

The overriding goal of calculating metrics is to provide a quantitative, and objective, means to determine what part of a slope channel 1-D well data passes through. The data are also useful for populating reservoir models that rely on limited subsurface information. Figure 1 shows an example cross section through a typical channel element found in the Tres Pasos Formation. McHargue et al (2010) describes the organization of a channel fill into the predictive pattern of facies associations: axis, off-axis, and margin, each of which is considered an intra-channel sub-environment. Relatively speaking, it is the degree of bed amalgamation, and the net-to-gross that defines these environments (Fig. 3).

Of the three sub-environments, the axis is located within the thickest part of the channel form, displays the greatest amount of amalgamation (ie, sandstone-on-sandstone contact), is characterised by the thickest sedimentation units, and has the highest proportion of sandstone (McHargue et al, 2010). In contrast, the margin sub-environment is located at the thinner edges of the channel element, displays the least amalgamation, the thinnest beds, and the lowest proportion of sandstone. The off-axis sub-environment is intermediate between the marginal and axial portions of the channel element. Two of the most valuable metrics are described below.

Net-to-gross

The thickness of sandstone / gross thickness of an interval of interest, or net-to gross, is a commonly used metric. Based on measurements of >3500 sedimentation units in this study, the net to gross is generally >90% for axis deposits, 75-80% for off-axis units, and 30-35% for sedimentary units associated with channel margin deposition (Fig. 3).

Amalgamation Ratio

An amalgamation surface is defined as a sandstone on sandstone contact between individual event beds. For reservoir modeling, this metric is particularly valuable as thin shale partings present between turbidity current deposits can reduce vertical permeability significantly. Where two beds are amalgamated, erosional processes has removed this vertical barrier to fluid flow. The amalgamation ratio is equal to the number of amalgamation surfaces in a channel element / (the total number of sedimentation units -1); subtracting one from denominator normalizes the metric since there is always one fewer bed contact than sedimentation unit in any given channel succession (see Romans et al., 2009 for additional information about the methodology). Channel axis units are characterized by an amalgamation ratio of ~60%, off-axis units 30-35%, and margin units < 10% (Fig. 3). This reflects the erosive nature of gravity flows that pass through the axial parts of channels.

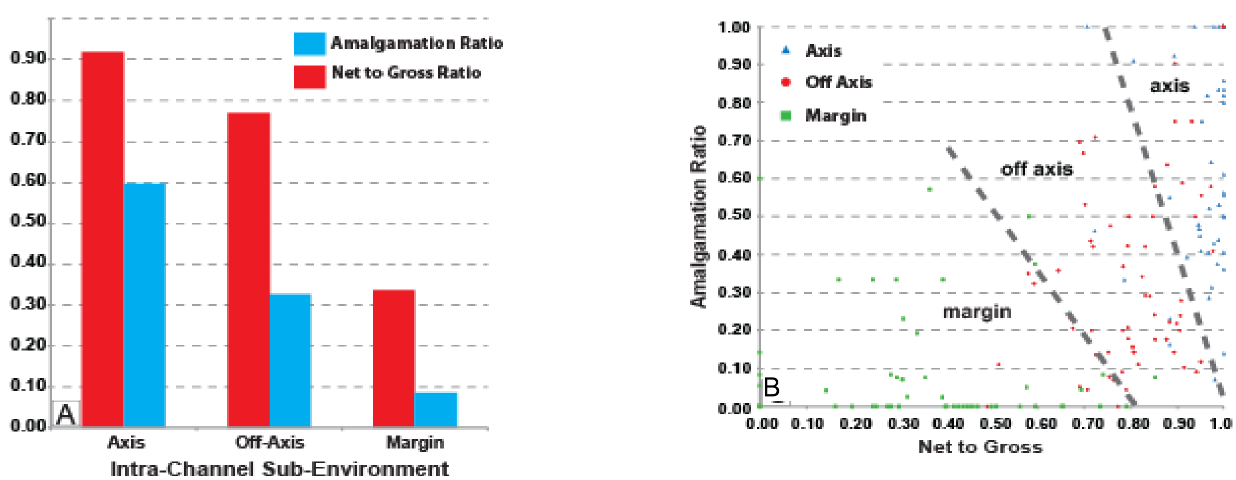

Figure 3- Net-to-gross and amalgamation ratio measurements taken from 182 channel packages in outcrop. This analysis includes characterization of >3500 individual sedimentation units.

References

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