The Orientation of Sandstone-Filled U-Shaped Trace Fossils as Indicators of Deepwater Channel Axis Position, Tres Pasos Formation, Chile*

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Abstract

Trace fossils are widely established indicators of paleo-environmental conditions, which augment interpretations of various sedimentary successions and processes. In the study of slope channel deposits, accurately constraining channel form body orientations is challenging, traditionally relying upon paleoflow measurements and lateral facies relationships in outcrop belts. We show that trace fossil orientation can be closely tied to the position and trend of paleochannel axes. Well-constrained channel form bodies of the Cretaceous Tres Pasos Formation, Chilean Patagonia, are characterized by thick amalgamated sandstone beds in their axes that transition to finer and thinner bedded units towards their margins. The 3-D nature of the channel forms in the outcrop belt have been constrained through mapping and paleoflow measurements; in the area of interest, the southward flowing channel form under investigation trends 175–190°. A dense population of vertical to sub-horizontal, elongate and u-shaped trace fossils penetrate alternating sandstone and mudstone beds of the channel margin to depths of up to 1.5 meters. The trace fossil shafts are 0.5–1.0 cm in diameter; they are generally sandstone-filled vertical to sub-horizontal paired burrows characterized locally by feint spreite (Diplocraterion-like). The orientation and attitude of 402 burrow pairs were measured in four distinct localities. Trace fossils located more proximal to the channel axis demonstrate a strong preferred alignment normal to the channel trend (271°) and are characterized by shallow plunge away from the channel axis (ave = 36°). Trace fossils located further from the channel form axis display more varied trends, with steeper shafts and less sub-horizontal segments (plunge ave = 70°). The preferred alignment of axis-proximal trace fossils is attributed to a suspension feeding strategy adapted to the passing of nutrient- and oxygen-rich flows that flowed along the channel thalweg. This strategy was apparently less advantageous adjacent to the channel edge (i.e., axis-distal), perhaps in response to more varied turbulent flow pathways associated with overspill from the channel axis, as well as reflection off of channel edges. These data suggest that trace fossil orientation can aid paleo-channel reconstruction in less well-constrained outcrops, and perhaps in core-constrained subsurface studies.
4. Slope System Context

The channel deposits are located 44 km from the mapped shelf edge, towards the lower portion of a high-relief clinoform. (A) Regional dip-oriented stratigraphic cross-section of the Tres Pasos and Dorotea formations, showing context of the deposits studied. (B) Channel systems are common in slope strata; when greater than 1000 m across and 50 m thick, they generally represent major channels features, comprised of numerous smaller channel mouth banks. The largest channels are resolvable in seismic data, however, the internal, smaller channel elements connect and form a complete system of cross-cutting channel elements. 10-20 m thick and 300 m wide, which is one of the most successful characteristic paleocurrent indicators and provide insight into the paleochannel axes.

5. Channel System Context

Stratigraphic cross-section shows the distribution of slope channel strata at Laguna Figueroa. The outcrop consists of a series of channel fills, which can be grouped into channel complexes. The ~11 m thick sedimentary package is exposed in five similar channel complexes, differentiated by unique channel fill stratigraphy. In the general Patagonian area, channel orientation is oriented with the channel axis normal to the clinoform trend (271°), and the channel fill strata are more strongly preferred alignment normal to the channel trend (271°). The channel fill strata are more strongly preferred alignment normal to the channel trend (271°). The channel fills are common in slope strata; when greater than 1200 m across and 50 m thick, they generally represent major channel features, comprised of numerous smaller channel mouth banks. The largest channels are resolvable in seismic data, however, the internal, smaller channel elements connect and form a complete system of cross-cutting channel elements. 10-20 m thick and 300 m wide, which is one of the most successful characteristic paleocurrent indicators and provide insight into the paleochannel axes.
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6. Gabriela Channel Overview and Trace Fossil Locations

Trending inclined trace fossils were identified at 7 different locations: Part A; Areas 1, 4, GCN, DSW, and GC4 along the Gabriela Channel expose open Laguna Figueroa. The trend and plunge of each trace fossil was measured, as were the strike and dip of the beds in which they are located. Palaeocurrent indicators, such as flute casts, tool marks, and ripples were collected at each location. The coordinates of each outcrop studied were registered on a black-mapped (GPS). Trace fossil and palaeocurrent orientation data were corrected by horizontal using recorded strikes and dips.

7. Oriented Trace Fossils: Observations

Three main trends are apparent from the measurements taken:

1. Adjacent to the channel axis in the proximal margin (sites: GCN and DSW), trace fossil orientations are aligned but now trend upcurrent, oriented and relatively parallel to the mapped channel margin. Trends in these data suggest that organisms preferentially oriented their burrows in response to physical or chemical conditions within the submarine conduit. Preferential orientation may have been employed to take advantage of nutrient-rich currents, or as a means to minimize erosion or burrow destruction from turbulent scour.

2. In the northern portion of the study area, deposition took place at a segment of the channel that was near straight for > 3 km up-slope. Towards the channel axis in a proximal margin setting (sites: GC4, Areas 1 and 2), trace fossil orientations are oriented and generally plunging away from the mapped channel axis. Could this trend be demonstrated quantitatively? Data were collected to determine whether the trace fossils, and particularly their orientation, might be useful for prediction of channel axis location.

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1. Adjacent to the channel axis in the proximal margins (sites: GCN, Areas 1 and 2) the trace fossils are aligned and generally oriented normal to palaeocurrent measurements and the mapped channel edge trend. Towards the channel axis in a proximal margin setting (sites: GCN and DSW), trace fossil orientations are aligned but now trend upcurrent, oriented and relatively parallel to the mapped channel margin.

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8. Trace Fossil Characteristics

U-shaped trace fossils are commonly attributed to suspension feeders; they descend vertically through alternating thin sandstone and mudstone beds, commonly transitioning to horizontal towards their terminus. The trace fossils are up to 1 m long and penetrate through 1-2 m of strata. The trace fossils are sandstone-filled (preserved positive relief), with shafts 0.8-1.5 cm in diameter. Taxonomically, the trace fossils are difficult to classify. Vertical trace fossils are commonly described as Arenicolites. However, when impossibly preserved, some trace fossils are characterized by fine spriets, which record progressive burrow extension into the substrate (or right). Vertical trace fossils characterized by spriets include Diplocraterion; however, there is a horizontal component to these structures, which in isolation may be better classified as Chondrites.

Examples of the trace fossils are presented in this section, below.

9. Discussion and Conclusions

Distinct, sandstone-filled U-shaped trace fossils are common in channel margin deposits in the Tres Pasos Formation, Chile. They are generally well aligned, and exhibit plunges that trend away from the paleo-channel axis. It seems apparent that organisms which colonize terraces towards the edges of channels preferentially orient their burrows in response to currents, and therefore, they may provide insight into channel axis position in oriented cores or limited outcrops.

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