KECK Geology Consortium
Learning Science Through Research
Published by Keck Geology Consortium
Short Contributions
29th Annual Symposium Volume
23rd April, 2016
ISBN: 1528-7491

PALEOCURRENT DIRECTIONS IN THE NANUSHUK FORMATION AT SLOPE MOUNTAIN, ALASKA

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INTRODUCTION

The Nanushuk Formation on the North Slope, Alaska (Fig. 1, Shimer and McCarthy, this volume) is an interesting candidate for paleocurrent analyses because it records the progradation of the topset portion of a massive depositional sequence into the Colville foreland basin (Decker, 2007). Paleocurrents in this formation can thus be used to determine from which direction the main source of sediment entered the basin. This can then be used to reconstruct mid to Late Cretaceous paleogeography in the region. On a more local scale, wave ripples in the Nanushuk can be used to interpret the local shoreline orientation, and changes in wave ripple crest orientations may reveal how the local shoreline changed as the basin evolved.

This study focuses on exposures of the Torok and Nanushuk formations at Slope Mountain, Alaska. The Albian to early Cenomanian sedimentary rocks of the Torok and Nanushuk formations represent the bottomset, foreset, and topset deposits of a prograding shelf system that progressively filled the Colville basin from west to east, with a north to south component along the orogenic front (Decker, 2007). The Torok Formation consists marine shale deposited on a developing continental shelf and slope (Mull et al., 2003), while the Nanushuk Formation comprises shallow marine, deltaic, and alluvial facies (LePain et al., 2009). The Nanushuk Formation has been dated primarily through examination of both microfossils and megafauna to be late Albian to early Cenomanian in its upper part (Mull et al., 2003). Grain size generally coarsens upwards, with shale less common up-section and conglomerate appearing in the upper Nanushuk Formation. This pattern is a record of depositional systems that transitioned to a terrestrial environment, most probably a meandering river system with alluvial plain and abandoned delta lobes recorded in the upper shale (LePain et al., 2009).

METHODS

A Brunton compass was used to determine bedding strike and dip, as well as ripple crest orientation at Slope Mountain (SM) sections 1, 1.1, 2, 3, 5, 6, and 7. Jacob staffs and tape measures were employed to measure the sections, and a tape measure was used in measuring the wavelength and height of ripples. The data was then plotted using Stereonet 7 software. Microsoft Excel was used to tabulate the data and perform analysis.

RESULTS

The consolidated measurements appear in Table 1. The dominant dip direction at most of the observed measured sections was to the west, as all sections lie on the eastern margin of the Marmot syncline (Fig. 3, Shimer and McCarthy, this volume). Observed ripples were predominantly symmetrical, straight-crested (two-dimensional) wave ripples, although some asymmetrical current ripples were also observed in these sections. Wave ripple crest spacing ranges from 4 cm to 15 cm, with an average of 8.6 cm. The wave ripple indices (crest spacing divided by heights) ranged from a maximum of 20, observed in SM2, and a minimum of 4, observed in SM5. There is one reading of 37.5, which is anomalous. Average ripple indices appear in Table 2.

Both wave and current formed ripples occur in the Nanushuk Formation, but wave ripples are dominant. Wave and current ripples within each measured section had similar crest strike orientations to each other. Six asymmetric ripples (current ripples) were measured, and in each case the paleocurrent was oriented generally towards the north quadrants. The wave oscillation directions in the Nanushuk Formation changes from northwest--southeast in the lower sections, gradually swinging to northeast--southwest and then back to northwest--southeast. Wave oscillation directions for each section are shown in the following rose diagrams.

For paleocurrents in the Torok Formation and transitional strata in the lower Nanushuk Formation (Fig. 1), SM1 has an average wave oscillation direction of NNW--SSE (340-160˚), while SM1.1 shows variable wave oscillation direction, and SM2 has a wave oscillation direction of NNW--SSE (20-200˚). SM6 shows variable wave oscillation direction, and SM7 has a wave oscillation direction of NE-SW (044-224˚). For sections fully within the deltaic deposits of the Nanushuk Formation (Fig. 2), wave oscillation direction in SM3 is NNW—SSE (354-174˚), and is oriented NNE--SSW (006-186˚) in SM5. The paleoshorelines indicated by these sections had strikes of 250-130˚ in SM1, 261-141˚ in SM1.1, 290-110˚ in SM2, 254-74˚ in SM3, 276-96˚ in SM5, 270-90˚ in SM6, and 314-134˚ in SM7.

DISCUSSION

Wave ripples can be classified according to the relationship between ripple wavelength and the orbital diameters (distance over which the water oscillates) of the waves that formed them. For one class of ripples, called orbital ripples, spacing scales directly with orbital diameter (Clifton and Dingler, 1984). For ripples formed under large orbital diameters, spacings (5-8 cm) do not scale directly to orbital diameter, and these are called anorbital ripples. The range of spacings of the ripples in the Nanushuk Formation is consistent with a classification as orbital ripples. Anorbital ripples tend to have long wavelengths and small amplitudes, and thus large ripple indices. The Nanushuk Formation ripples have ripple indices that are consistent with orbital ripples. Assuming these ripples are orbital, it would be possible to calculate a range of potential wave conditions and water depths, although no unique solution is possible.

The wave ripple orientations agree with the findings of Johnson and Sokol (1998) for the regional paleocurrent directions in the Nanushuk, and differ slightly from the east--northeast trend of Bird and Molenaar (1992). The dominant offshore current direction is roughly north, with variation to both the northeast and northwest (Fig. 1 and 2), a radial pattern that may be related to the progradation of a delta lobe. As both wave and current ripple crests form parallel to the shoreline orientation (Leckie & Krystinik, 1989), this data can be used to track the orientation of the wave-influenced paleoshoreline over time. Changes in paleoshoreline orientation are to be expected in a prograding delta system such as the Nanushuk-Torok formation set, and shorelines that transitioned from northeast to northwest and back again likely reflect autogenic changes in dominant delta lobe deposition. Basin evolution could also have been a factor, in which case the dominant sediment source in the southeast would have slowly switched to a source in the southwest, and then returned to a southeastern source.

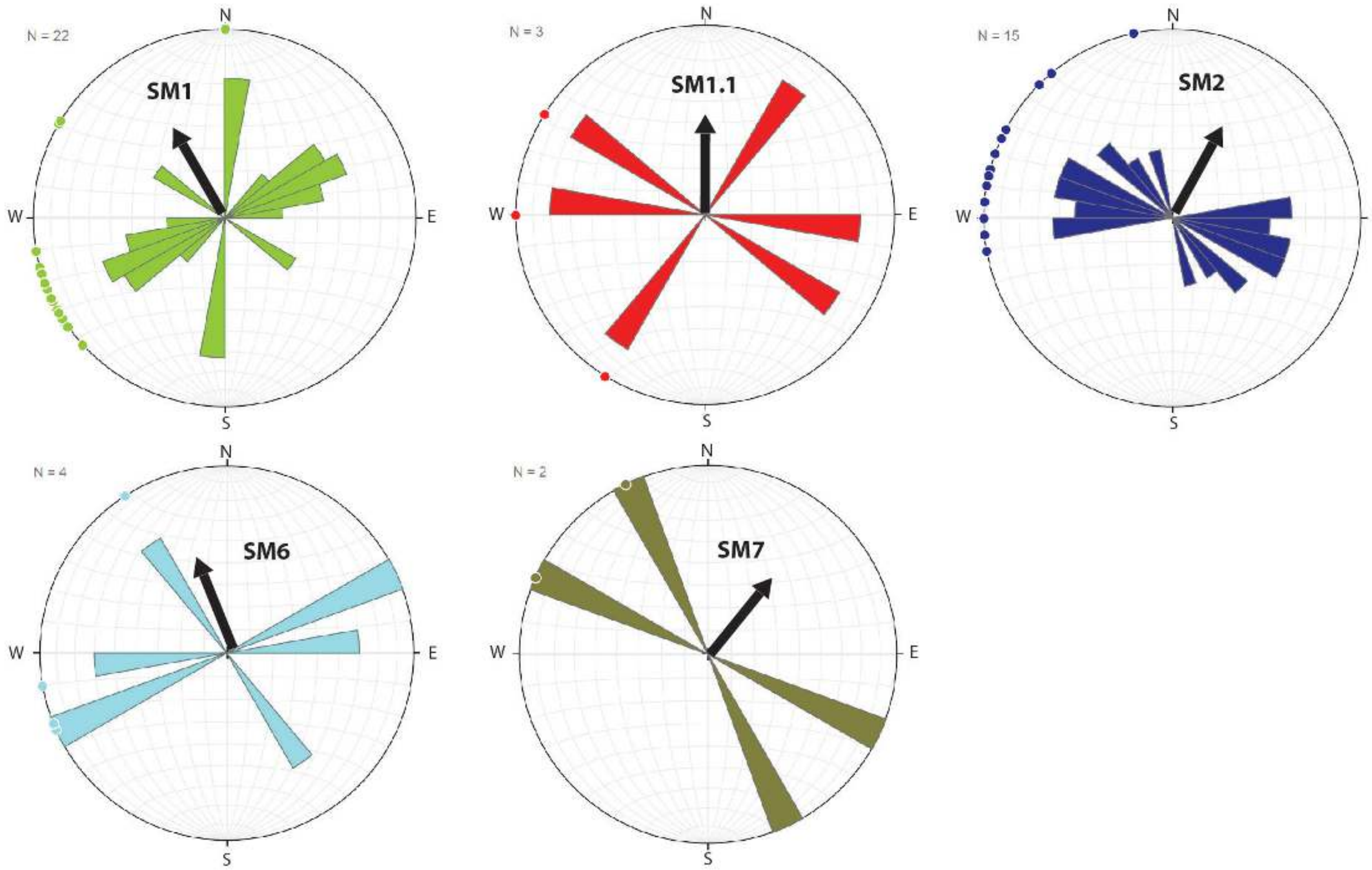

Figure 1. Diagrams illustrate the ripple crest orientation measurements taken Slope Mountain (SM) sections within the Torok Formation and lowermost marine and marginal marine component of the Nanushuk Formation. Diagrams oriented with north (N) towards the top, and the number of measurements (N=X) listed in the upper left corner. Ripple oscillation or current direction are assumed to be perpendicular to crest orientation. Black arrows depict interpretation of dominant offshore current direction.

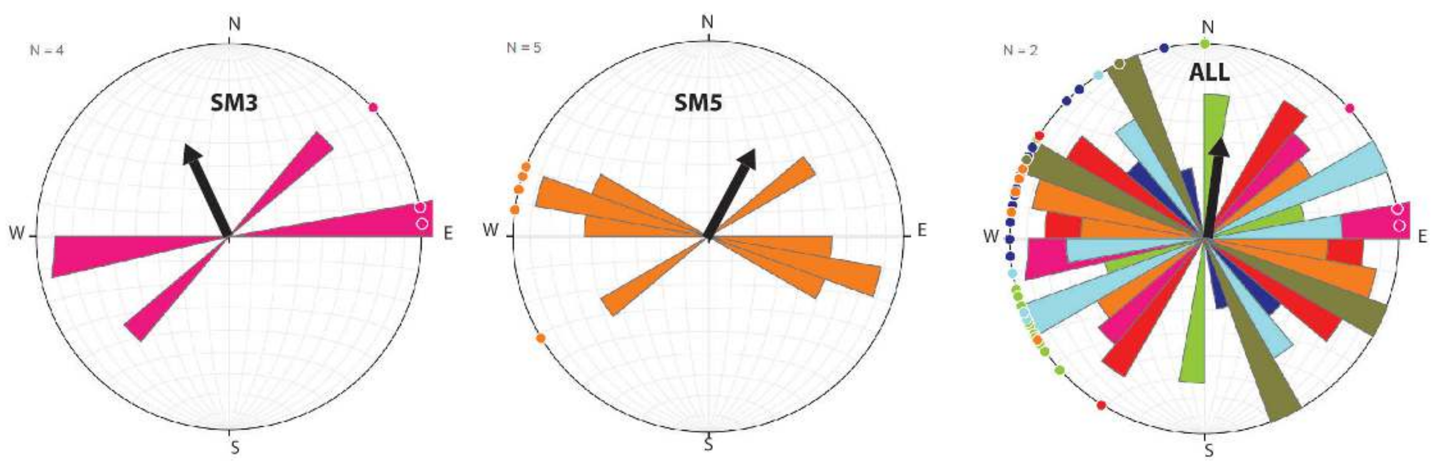

Figure 2. Diagrams illustrate the ripple crest orientation measurements taken Slope Mountain (SM) sections within the deltaic component of the Nanushuk Formation, as well as a comprehensive diagram depicting all paleocurrent measurements at Slope Mountain. Diagrams oriented with north (N) towards the top, and the number of measurements (N=X) listed in the upper left corner. Ripple oscillation or current direction are assumed to be perpendicular to crest orientation. Black arrows depict interpretation of dominant offshore current direction.

Table 1. Compiled paleocurrent measurements at Slope Mountain.

Section	Section Elevation (m)	Sample Type (ripple type)	Crest Spacing	Paleocurrent Measurement	Formation
SM1	46.1	Wave	7	325	Torok-Nanushuk
SM1	44.4	Wave	10	318	Torok-Nanushuk
SM1	44.0	Wave	11	330	Torok-Nanushuk
SM1	42.8	Wave	6	335	Torok-Nanushuk
SM1	41.25	Wave	8	350	Torok-Nanushuk
SM1	38.3	Wave	7	331	Torok-Nanushuk
SM1	37.1	Wave	5	328	Torok-Nanushuk
SM1	36.65	Wave	11	340	Torok-Nanushuk
SM1	36.0	Wave	15	31	Torok-Nanushuk
SM1	34.5	Wave	9	334	Torok-Nanushuk
SM1	34.0	Wave	7	343	Torok-Nanushuk
SM1	32.84	Current	6	325	Torok-Nanushuk
SM1	32.08	Current	8	30	Torok-Nanushuk
SM1	17.0	Current	5	327	Torok
SM1	14.6	Current	5.5	345	Torok
SM1	7.25	Wave	4	338	Torok
SM1.1	9.3	Wave	7	360	Nanushuk
SM1.1	5.0	Wave	10	302	Nanushuk
SM1.1	3.55	Wave	7.5	32	Nanushuk
SM2	47.0	Wave	10	355	Torok
SM2	23.2	Wave	8	20	Torok
SM2	18.0	Wave	10	355	Torok
SM2	16.0	Current	9	25	Torok
SM2	14.6	Wave	13	50	Torok
SM2	14.1	Wave	12	350	Torok
SM2	12.55	Wave	8	360	Torok
SM2	10.9	Wave	6	13	Torok
SM2	8.6	Wave	10	10	Torok
SM2	7.2	Wave	8	78	Torok
SM2	6.5	Wave	12	15	Torok
SM2	6.04	Wave	8	28	Torok
SM2	3.0	Wave	6.5	5	Torok
SM2	2.05	Wave	7	45	Torok
SM2	0.85	Wave	8	45	Torok
SM3	4.61	Wave	8	351	Nanushuk
SM3	2.6	Wave	10	351	Nanushuk
SM3	2.6	Wave	7.5	356	Nanushuk
SM3	2.2	Wave	11	318	Nanushuk
SM5	4.25	Wave	9	21	Nanushuk
SM5	3.8	Wave	10	18	Nanushuk
SM5	3.0	Wave	13	14	Nanushuk
SM5	2.44	Current	11	329	Nanushuk
SM5	1.0	Wave	6	8	Nanushuk
SM6	3.0	Wave	8	57	Torok-Nanushuk
SM6	1.5	Wave	10	338	Torok-Nanushuk
SM6	1.03	Wave	9	336	Torok-Nanushuk
SM6	0.6	Wave	7	350	Torok-Nanushuk
SM7	1.2	Wave	7	24	Nanushuk
SM7	1.0	Wave	10	64	Nanushuk

Section	Avg. Ripple Indices
SM1	10.6
SM1.1	9.4
SM2	13.9
SM3	6.2
SM5	8.0
SM6	6.9
SM7	12.0

Table 2. Averaged ripple indices for each Slope Mountain section with measurements.

ACKNOWLEDGEMENTS

I would like to thank Professors Grant Shimer and Paul McCarthy for leading this project, and the Keck Geology Consortium and its director, Robert Varga and assistant Carol Morgan for making this project possible. I would also like to thank my on-campus advisor, Professor Paul Myrow, for his assistance in writing up this project.

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