Factors Controlling Organic Richness of the Upper Bakken Shale

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Abstract

Organic richness in shale is primarily controlled by the interplay of three factors: organic productivity, preservation and dilution by sediments. This study is focused on understanding the impact of these factors on organic richness of Upper Bakken Shale (UBS), for which the Total Organic Carbon (TOC) varies between 3-20 wt.%. A conceptual model for the accumulation and preservation of organic matter (OM) in UBS is also proposed. The framework of this conceptual model includes the depositional setting of the basin, including basin morphology, paleogeography, paleoclimate, and probable nutrient sources. This study is based on the results of the following three analyses: 1) induced coupled plasma mass spectrometry (ICP-MS) for elemental concentration measurements; 2) source rock analysis (SRA) for TOC and OM characterization; and 3) stable isotope measurements for carbon and nitrogen. These analyses were performed on 40 core chips of UBS from well Robert Trust 1-13H, which is located at the southern depocenter of the Williston Basin. Elemental concentration of Si, Al, K, Ti, and Ca were used for proxying the effect of dilution and preservation of OM by detrital and biogenic sediments. The concentration of the redox-sensitive trace elements (MO, U) and degree of pyritization (DOP) were used as proxies for understanding the variation in paleoredox condition during the deposition of the UBS. Stable isotopes of organic carbon and nitrogen were used to understand the OM type in the UBS and the paleoproductivity during its deposition. Our results suggest that TOC and the factors which controlled the organic richness varied in the southern depocenter of the basin during the deposition of the UBS. It is proposed that the basin was semi-restricted, with a stratified water column, and regeneration of the biolimiting nutrients such as P and N the major source of nutrients. These conditions varied during the deposition

of the UBS, primarily due to a relative change in sea level, which resulted in four distinct sub-units in the UBS: 1a, 1b, 2a, and 2b. An influx of clay had a positive effect on organic-richness during the deposition of all four sub-units. Biogenic silica had a dilution effect during the deposition of organic matter in sub-units 1a and 1b. Detrital dolomite and siliciclastic silt also had a dilution effect during the deposition of sub-units 2a and 2b. Sub-units 1a and 1b were deposited in a strongly euxinic condition, which existed in the bottom water and extended to the photic zone intermittently. During the deposition of sub-units 2a and 2b, the conditions were predominantly sub-oxic to anoxic along the sediment water interface. Paleoproductivity was high during the deposition of sub-units 1a and 1b, and paleoproductivity declined during the deposition of sub-units 2a and 2b.