

Remote Detection of Anomalous Mineralogy Associated With Hydrocarbon Production, Lisbon Valley, Utah¹

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ABSTRACT

Examination of a variety of remotely sensed data and geochemistry suggest that specific diagenetic mineral assemblages within the Wingate Formation are closely associated with hydrocarbon production at Lisbon Valley, Utah. The Wingate Formation, exposed along the southwestern flank of the anticline has a relatively uniform composition and appearance over the entire Colorado Plateau, except at isolated localities such as Lisbon Valley, where it is locally bleached. Previous workers have suggested that hydrocarbon microseepage may account for the bleaching of the Wingate Sandstone and the presence of uranium mineralization in rocks overlying the reservoir at Lisbon Valley. Broad-band Landsat Multispectral Scanner (MSS) and airborne Thematic Mapper Simulator (TMS) data were used to map the bleached facies on the basis of brightness and lack of ferric iron. The TMS data provided further discrimination of bleached facies based on the relative abundances of clay minerals detectable with this sensor.

Analysis of high-resolution airborne spectroradiometric data, thin sections, and x-ray diffraction data suggests that bleached rocks overlying the reservoir at Lisbon Valley contain abundant kaolinite and minor amounts of feldspar. Unbleached exposures contain substantially less clay and abundant feldspar. This study shows a correlation between the abundance of clay minerals, particularly kaolinite, and hydrocarbon production at Lisbon Valley. Because one of the principal mineralogical differences between the bleached and unbleached rocks is the relative abundance of clay minerals, and the TMS (and Landsat Thematic Mapper) data are very sensitive to clays, areas of potential hydrocarbon induced diagenetic alteration may be mapped using broad-band sensors.

INTRODUCTION

Lisbon Valley is a northwest-trending doubly plunging anticline located in San Juan County, Utah (Figure 1). The anticline is a nondiapiric salt-cored fold which has been breached by erosion and undergone subsequent collapse. Cuestaform ridges and hogback structures are well developed on the southwest limb of the anticline.

The stratigraphic sequence exposed at Lisbon Valley includes units from the Pennsylvanian Hermosa Group through the Cretaceous Dakota Sandstone. Pre-Paradox formations of Mississippian, Devonian, and Cambrian age underlie the exposed sequence. Mississippian, Devonian, Pennsylvanian, and Permian rocks produce hydrocarbons at Lisbon Valley.

The Late Triassic Wingate Formation is easily recognized as an orange red, thick bedded, erosion resistant, cliff forming sandstone prominently displayed in the southwest dipping cuesta of the west flank of the Lisbon Valley anticline. Steep to vertical cliffs display pervasive vertical joints, tangential cross-bedding on a grand scale, and may show the effects of spalling of huge blocks of sandstone along vertical joint faces.

The Wingate Formation is bleached on the southwest flank of Lisbon Valley anticline in the Three Step Hill and Lisbon field areas (Figure 1). In these areas the Wingate is gray and displays anomalous mineralogical and weathering patterns. Effects include anomalous carbonate and limonite concentrations and the transformation of the Wingate Formation from an erosionally resistant sandstone to a friable unit which weathers easily into small bleached mounds.

Petroleum Geology

The Lisbon field produces oil and gas from the southwest flank of a faulted anticlinal trap in the Devonian McCracken Sandstone and the Mississippian Redwall (Leadville) Limestone. Additional gas production from the Redwall along this flank of the anticline is present at the Little Valley field (Latch, 1978), located about 1 mi (1.6 km) updip from the Three Step Hill area. The crest of the Mississippian structure is located approximately 4 mi (6.4 km) west of the axis of the Lisbon Valley salt anticline. The disparity of the pre- and post-Pennsylvanian structures suggests that field production is related to basement structure that predates the salt deposition (Clark, 1978). Accumulation in the Mississippian at the Lisbon field is controlled by a fault on the northeast side of the structure, which exhibits a throw of 1,200–1,600 ft (366–488 m), and by an oil water contact downdip. Closure of the structure is estimated at 1,900 ft (579 m), with an associated 1,800 ft (549 m) oil column (Clark, 1978). Thus, the hydrocarbon reservoir is filled almost to the spill point, making it an ideal location for study of the effects of vertical leakage.

Conel and Neisen (1981) have documented the close spatial correlation between commercial uranium deposits, exposures of bleached Wingate Sandstone, and the spatial distribution of oil and gas production at Lisbon Valley (Figure 2). Sour gas leaking from the hydrocarbon reservoir is believed to have created a reducing and acidic environment that mobilizes and redeposits previously stable ferric iron oxide minerals as sulfides, contributes to uranium mineralization, and geochemically controls many of the other mineralogical anomalies present in the rocks overlying the production.

Hydrocarbon Microseepage

Oil and gas seeps have long been used in exploration for hydrocarbons. Roberts (1980) defined a hydrocarbon trap as a dynamic membrane that leaks aqueous fluids and impedes the flow of hydrocarbons, implying that microseepage of hydrocarbons from a reservoir is a more common occurrence than previously recognized. Direct evidence of microseepage of

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