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Mineralogy and Diagenesis of Core Samples of Upper Cretaceous Sandstones, Twin Arrow Inc. 4-14X C and K Well, Piceance Creek Basin, Northwestern Colorado

by

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Introduction

Sandstone core samples examined for this study are from the Twin Arrow Inc. 4-14X C and K well (sec. 14, T. 3 S., R. 101 W.) on the Douglas Creek arch near the western margin of the Piceance Creek basin in northwestern Colorado. These sandstones occur in a transition zone between the nonmarine and marine parts of the Mesaverde Group at depths ranging from 1,005.4 to 1,144.2 ft. The cored interval crops out less than 3 miles north of the drill site. Gas production from the Twin Arrow well is from beds of the Emery Sandstone Member ("Mancos B" of some authors) of the Mancos Shale.

This study is part of a continuing evaluation of the mineralogy and diagenesis of tight (< 0.1 millidarcies) Upper Cretaceous nonmarine sandstone in the Piceance Creek basin, northwestern Colorado. Examination of eight thin sections from selected core samples revealed that these are not tight sandstones; this observation was confirmed by measured porosity and permeability values. The shallow depth of these sandstones is suspected to have caused them to be subject to infiltration and extensive diagenetic alterations by ground water.

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Detrital Mineralogy

Thin sections were impregnated with blue epoxy, stained with sodium colbaltinitrate for potassium feldspar, and Alizarin Red S for calcite determinations. Mineral compositions based on 300-point counts of these thin sections are tabulated in table 1, measured porosity and permeability data are shown in table 2.

Detrital grains are predominantly angular to subangular, very fine to medium grained quartz, feldspar, chert, lithic fragments, and miscellaneous grains. Quartz grains are clear, occasionally undulatory, and commonly display euhedral overgrowths. Potassium feldspar is generally more common than plagioclase; however, this may be an artifact of diagenesis because plagioclase has undergone more diagenetic alteration. Most plagioclase has either been altered to clay, sericite, or has been dissolved leaving large, open pores. Argillaceous rock fragments are the most common lithic grains but small amounts of metamorphic, granitic, and unidentifiable lithic fragments are present in all samples. Lithic fragments, as expected, were found to be more common in the coarser grained sandstones. Highly altered rock fragments that may be volcanic (andesitic) in origin were noted; however, the cloudy alteration and microcrystalline nature of these fragments made identification in thin section difficult. Metamorphic rock fragments are metaquartzite and schistose (chloritic) varieties. Angular chert grains are present in all samples.

Miscellaneous detrital constituents include muscovite (as much as 1 percent), biotite, chlorite, zircon, pyroxene, hornblende, tourmaline (dravite), pyrite, marcasite(?), and organic matter. Organic matter is common locally, particularly in the finer grained sandstones; in most samples it is concentrated in discrete laminae.

Table 1.--Results of 300-point counts of thin sections from sandstone samples, Twin Arrow core, northwestern Piceance Creek basin (Values in volume percent)

Sample depth (feet)	Quartz	Plagio-clase	K-feldspar	Chert	Rock fragments	CO_3 cement	Matrix + SiO_2 cement + organic matter	Porosity	Other[1]
1005.4	42.4	1.2	3.4	2.0	7.2	2.3	25.2	13.1	3.2
1040.0	54.7	0.0	0.5	2.9	9.5	1.4	8.3	21.3	1.4
1041.5	47.4	0.3	1.2	9.5	3.5	3.4	7.7	22.0	5.0
1042.7	42.8	0.4	1.8	2.3	7.1	2.8	19.6	19.0	4.3
1052.4	44.9	0.0	3.6	3.3	5.3	4.7	14.0	21.3	2.9
1135.5	36.5	0.8	2.5	3.0	19.8	0.0	8.7	22.7	6.0
1143.5	34.8	0.7	1.6	1.8	8.5	8.1	17.3	17.3	9.9
1144.2	36.0	4.2	2.3	1.9	9.2	4.2	13.3	21.3	7.6

[1]Altered grains and accessory minerals.

Table 2.--Measured permeability and porosity values, Twin Arrow core, northwestern Piceance Creek basin (data from Core Labs)

Sample depth (feet)	Permeability (millidarcies)	Porosity (percent)
1005.4	1.3	15.6
1040.0	249.0	23.5
1041.5	241.0	22.9
1042.7	175.0	24.6
1052.4	16.0	19.0
1135.5	33.0	19.9
1143.5	25.0	19.5
1144.2	17.0	19.2

Table 3.--X-ray diffraction analyses of < 2 micron fraction of Twin Arrow sandstones showing kaolinite:illite and dolomite: calcite peak intensity ratios

Sample depth (feet)	Kaolinite:illite	Dolomite:calcite
1005.4	6.4	2.5
1031.0	2.1	4.2
1040.0	5.1	5.0
1041.5	6.5	2.5
1042.7	2.2	0.7
1052.4	5.0	2.5
1143.5	5.4	9.0
1144.2	4.4	2.0

Diagenesis

Clay-mineral matrix and carbonate cement are abundant in these sandstones. Much of the clay matrix is authigenic; however, some appears to be pseudomatrix derived from the alteration of lithic fragments. X-ray diffractograms of the < 2 micron fraction revealed abundant kaolinite, less-common illite, dolomite as the major carbonate cement, and a small amount of calcite (table 3). Kaolinite occurs as a ubiquitous pore-filling clay in thin section; illite and chlorite were noted as occurring sporadically. Small, noncoalescing, quartz overgrowths occur in most samples, and, locally, where several quartz grains are nearly in contact, the overgrowths have joined to form a solid pocket of silica.

Secondary moldic porosity has resulted from the extensive leaching of grains and carbonate cements. Partial leaching of plagioclase grains has commonly left only a shell of the original framework grain. Dissolution of early(?) carbonate cements, which filled pores and replaced detrital grains, has created moldic and intergranular porosity that is largely responsible for the high porosity values of these sandstones.

Discussion

Compaction of these sandstone beds has been minimal as evidenced by the occurrence of grains completely surrounded by cement and "floating" in pores. Early cementation by calcite and dolomite may have inhibited compaction and later solution of these carbonate cements and labile grains appears to account for the high porosity found in these sandstones today. Much of the secondary porosity formed by dissolution is interpreted to have resulted from the leaching of these near-surface sandstones by ground water. Many pores created by dissolution of grains and (or) cement have subsequently been filled with kaolinite derived from both the alteration of detrital grains and precipitation from pore waters. Abundant kaolinite occurs in equivalent Mesaverde strata to the south at Hunter Canyon (Johnson and others, 1980). Authigenic chlorite was observed in only one thin section, where it occurs as rims oriented perpendicular to detrital grain surfaces or in pore throats, although it has been identified as a major permeability-reducing agent in other Upper Cretaceous sandstones in the Piceance Creek basin (Hansley and Johnson, 1980).

The stratigraphically youngest sample (1,005.4 ft), a very fine grained sandstone, has the lowest permeability and porosity values and a high kaolinite-illite ratio. Porosity, although lower than in the other samples, is still good and is moldic in nature. Permeability is much lower than in the other samples because of the poor sorting of grains, abundant organic matter, and clay matrix. Local patches of dolomite and barite(?) are also present.

Samples from depths of 1,040.0, 1,041.5, and 1,042.7 ft have the highest porosity and permeability values. Grain sizes are fine to medium; the sandstones are better sorted and the grains are more rounded than those of the other sandstones. Clay-mineral matrix is common, but organic matter and clay matrix are less abundant. All three samples have well-developed quartz overgrowths which, because they are localized, do not greatly affect the permeability.

The sample from a depth of 1,052.4 ft is similar mineralogically to the previous three; however, it is finer grained and more poorly sorted, accounting for the lower porosity and permeability.

Sandstone samples from 1,135.5, 1,143.5, and 1,144.2 ft have lower permeabilities than the other samples. The limiting factors appear to be abundant kaolinite in the pores, as well as illitic matrix and dolomite cement; however, porosity values of all three samples are high because of leached grains and cement.

Summary

These shallow sandstones are characterized by high porosity and permeability interpreted as having been caused by the percolation of ground waters. In contrast, stratigraphically equivalent, more deeply buried rocks of the Mesaverde Group from other parts of the basin have low permeability and lower, somewhat more variable, porosity (Hansley and Johnson, 1980). The physical presence of authigenic clay-mineral matrix, pseudomatrix, organic matter, and carbonate cements has locally reduced the permeability of some of the sandstones in Twin Arrow well which otherwise have high porosity values. The overwhelming diagenetic influence, however, is apparently that of the leaching of framework grains and cements from these sandstones by near-surface waters.

References Cited

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