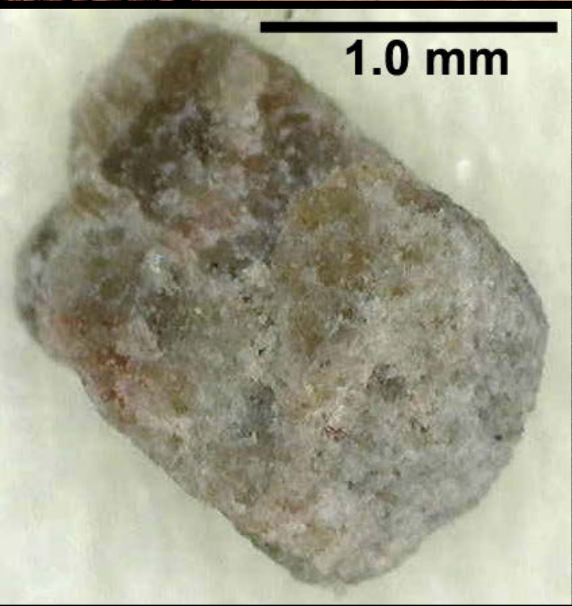
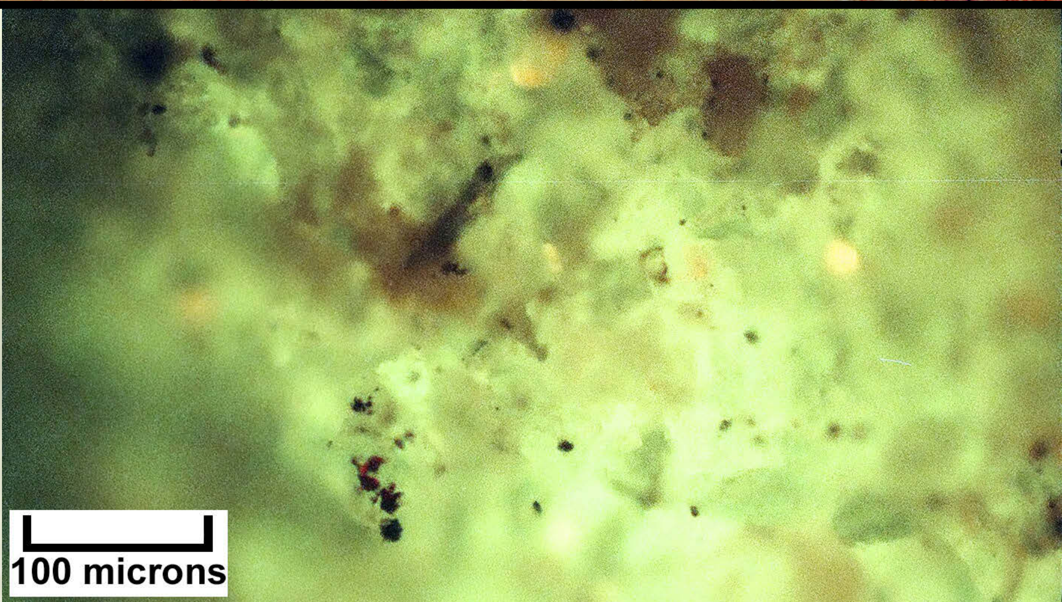
POTENTIAL OIL-PRONE AREAS IN THE CANE CREEK SHALE PLAY, PARADOX BASIN, UTAH, IDENTIFIED BY EPIFLUORESCENCE MICROSCOPE TECHNIQUES

by Thomas C. Chidsey, Jr., and David E. Eby





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Cover photo: *Top photo: Panorama of the Cane Creek anticline (middle ground); view east from Dead Horse Point State Point overlook. Bottom left photo: Microscope image of a single cutting from the Long Canyon No. 1 well, Long Canyon field, Grand County, Utah, showing light gray to medium brown, medium crystalline dolomite containing intercrystalline porosity, from the productive B interval of the Cane Creek shale, Pennsylvanian Paradox Formation, Paradox Basin, southeastern Utah. Bottom right photo: Photomicrograph of the same sample showing patchy, bright epifluorescence indicating a very good potential for movable oil and the capability of production. The vertical Long Canyon No. 1 well has produced over 1 million barrels of oil since its discovery in 1962.*

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POTENTIAL OIL-PRONE AREAS IN THE CANE CREEK SHALE PLAY, PARADOX BASIN, UTAH, IDENTIFIED BY EPIFLUORESCENCE MICROSCOPE TECHNIQUES

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ABSTRACT

The Cane Creek shale of the Pennsylvanian Paradox Formation has produced over 7.8 million barrels of oil and about 7.9 billion cubic feet of gas from 18 fields in the Paradox Basin of southeastern Utah. Potential oil-prone areas in the Cane Creek play area were identified in the northern part of the basin based on hydrocarbon shows recognized using nondestructive epifluorescence (EF) microscope techniques on cuttings, core chips, and uncovered thin sections. Approximately 2650 individual cuttings samples and core chips were evaluated from 31 wells penetrating the Cane Creek shale throughout the region. The wells include seven producers, one having cumulative production of >1 million barrels of oil from the Cane Creek since its completion in 1962.

The Cane Creek shale is divided into three intervals, based on wireline geophysical well-log characteristics and lithology, referred to as the A, B, and C intervals; the B interval is the primary oil producer. Finely crystalline dolomites and sandstones in the B interval have been the main targets of horizontal drilling. The dolomites in these intervals display intercrystalline porosity and microbial constructional pores whereas sandstones exhibit intergranular porosity; both rock types contain microporosity and fracture porosity. A new, qualitative visual EF rating was developed and applied to the group of samples from each cuttings sample interval in each well. The highest, average highest, highest average, and average of the sample averages of the EF ratings from each well were plotted and mapped for the entire Cane Creek as well as the A, B, and C intervals.

As expected, productive wells (fields) are distinguished by their generally higher EF ratings. However, an area of moderate to good fluorescence (indicating probable capacity of some oil production if there is adequate porosity and permeability) is indicated within a northwest- to southeast-oriented curvilinear fairway in the Cane Creek shale of the Paradox fold and fault belt. In contrast, the northeastern area shows a regional trend of low EF. This implies that hydrocarbon migration in Cane Creek dolomite, sandstone, and other porous lithologies was along regional northwest-trending folds, faults, and fracture zones, and created a potential oil-prone area that to date is relatively untested.

INTRODUCTION

The Cane Creek shale of the Pennsylvanian (Desmoinesian) Paradox Formation has produced over 7.8 million barrels of oil (MMBO) and about 7.9 billion cubic feet of gas (BCFG) from 18 fields in the Paradox Basin of southeastern Utah (figures 1 and 2) (Utah Division of Oil, Gas and Mining, 2016). The Cane Creek consists of naturally fractured and overpressured, thin dolomitic sandstone/siltstone and dolomite interbedded with anhydrite and organic-rich marine shale (Smith, 1978; Morgan, 1992; Grove and others, 1993). Petroleum is usually trapped in fractured dolomites and sandstones, on subtle subsidiary structural noses along major southeast-northwest-trending salt-cored regional anticlines, or on the crests of other smaller anticlinal closures. Since the early 1990s, horizontal drilling has been used to successfully develop the Cane Creek "tight" oil play. However, large areas in the Paradox Basin remain untested and possibly contain Cane Creek oil.

In environmentally sensitive areas of the Paradox Basin, prospect definition in the Cane Creek play often requires expensive, three-dimensional seismic acquisition. For this study, potential oil-prone areas in the play were identified based on mapping of hydrocarbon shows recognized using innovative, comparably low cost, noninvasive and nondestructive epifluorescence (EF) microscope techniques on cuttings, core chips, and thin sections. The dolomites in Cane Creek well cuttings and cores display intercrystalline porosity, and microbial constructional pores whereas sandstones exhibit intergranular porosity; both rock types contain microporosity and fracture porosity. EF microscope techniques enable better imaging of poorly preserved textures and grains in carbonate rocks, particularly dolomites. In addition, EF provides information on diagenesis, pore types, and organic matter (including "live" hydrocarbons) within sedimentary rocks. It is a rapid procedure that uses a petrographic microscope equipped with reflected-light capabilities, an Hg-vapor lamp, and appropriate filtering. The resulting EF show maps provide an assessment of the northern Paradox Basin that can be used to high-grade areas for (1) more detailed Cane Creek evaluations (such as seismic surveys), (2) lease acquisition, and (3) exploratory drilling.

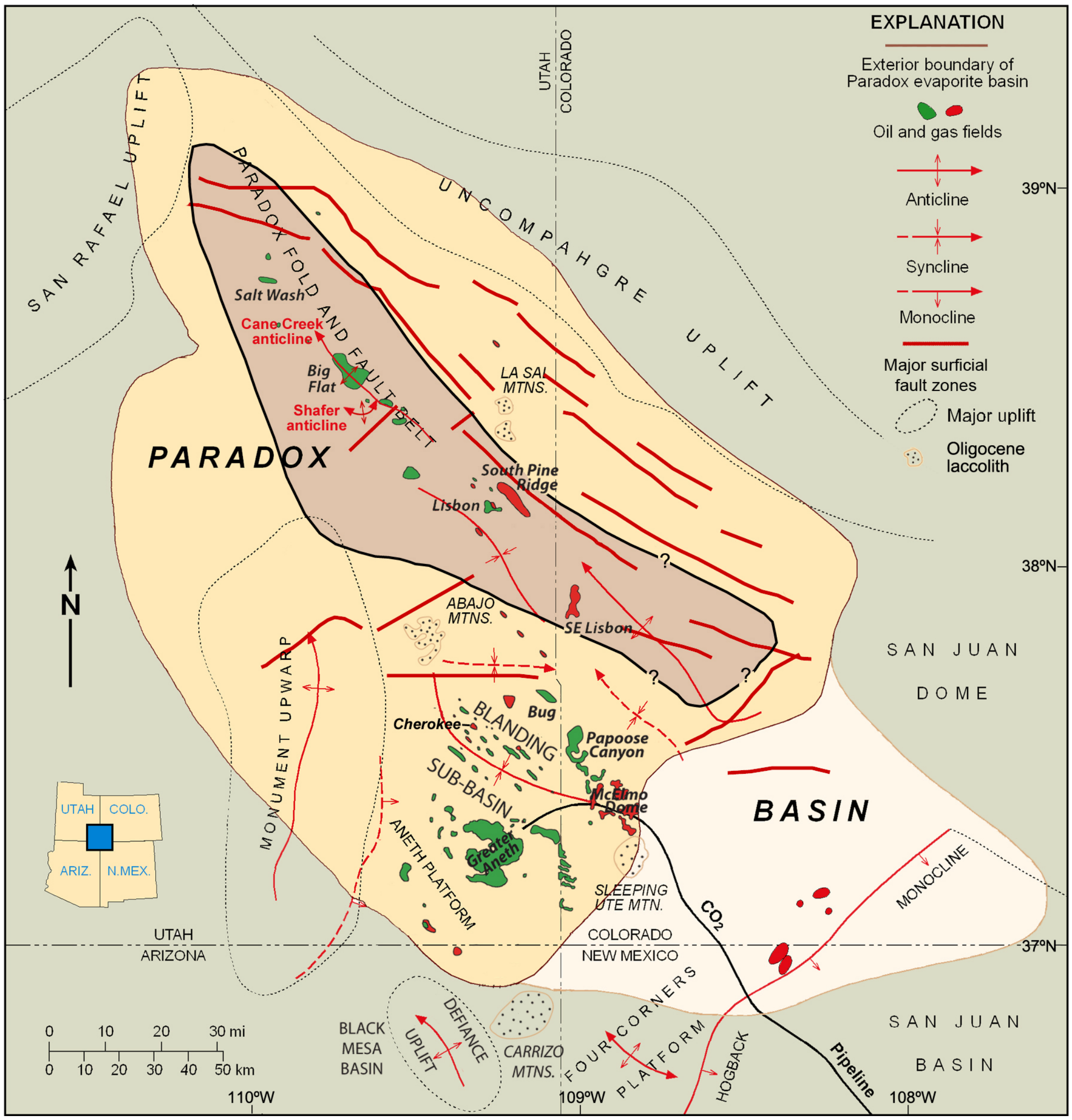

Figure 1. *Oil and gas fields in the Paradox Basin of Utah, Colorado, Arizona, and New Mexico. Modified from Harr (1996). The extent of Pennsylvanian Paradox Formation is shown in light orange; the Cane Creek shale play area within is light brown.*

GEOLOGIC OVERVIEW OF THE CANE CREEK SHALE

Paradox Basin

The Paradox Basin is located principally in southeastern Utah and southwestern Colorado and has small portions in northeastern Arizona and the northwestern corner of New Mexico (figure 1). The Paradox Basin is an elongate, northwest-southeast-trending, evaporite-rich basin that developed predominately during the Pennsylvanian, about 330 to 310 million years ago. The dominant structural features in the basin are surface anticlines that extend for miles in the northwesterly trending fold and fault belt (figure 1). During Cambrian through Mississippian time, this region, as well as most of eastern Utah, was the site of typical marine deposition represented by a relatively thin stratigraphic section on a craton with thicker deposits in a miogeocline to the west (Hintze and Kowallis, 2009). However, major changes began in the Pennsylvanian when a pattern of basins and fault-bounded uplifts developed from Utah to Oklahoma. One result of this tectonism was the uplift of the Ancestral Rockies in the western United States, including the Uncompahgre Highlands (uplift) in eastern Utah and western Colorado.

The Uncompahgre Highlands are bounded along their southwestern flank by a stack of large basement-involved, high-angle, reverse faults identified from seismic surveys and exploration drilling (Frahme and Vaughn, 1983; Kluth and DuChene, 2009). As the highlands rose, an accompanying depression, or foreland basin, formed to the southwest—the Paradox Basin. Rapid basin subsidence, particularly during the Pennsylvanian and continuing into the Permian, accom-

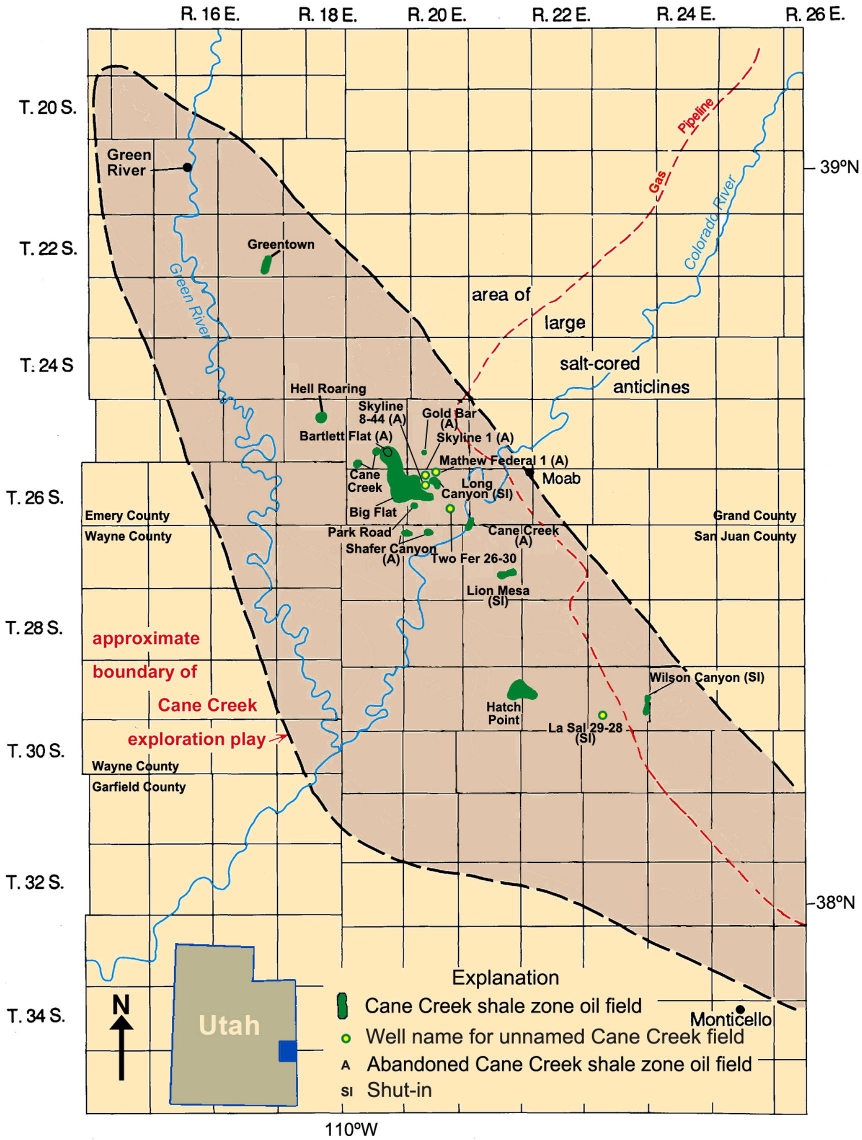

Figure 2. *Location of fields that produce from the Cane Creek shale and play area (light brown) within the Paradox Basin of southeastern Utah.*

modated large volumes of evaporitic and marine sediments that intertongue with non-marine arkosic material shed from the highland area to the northeast (Hintze and Kowallis, 2009). Deposition in the basin produced the thick cyclical sequence of carbonates, evaporites, and organic-rich shale that comprise the Paradox Formation.

The Paradox Basin can generally be divided into three areas: the Paradox fold and fault belt in the north, the Blanding subbasin in the south-southwest, and the Aneth platform in the southernmost part in Utah (figure 1). The area now occupied by the Paradox fold and fault belt was also the site of greatest Pennsylvanian/Permian subsidence and salt deposition. The area was created during the Late Cretaceous through Quaternary by a combination of (1) reactivation of basement normal faults, (2) additional salt flowage followed by dissolution and collapse, and (3) regional uplift (Doelling, 2003; Trudgill and Paz, 2009).

Stratigraphy and Thickness

The Paradox Formation is part of the Pennsylvanian Hermosa Group (figure 3). The 500- to 5000-foot-thick (150–1500 m) Paradox Formation is overlain by the Honaker Trail Formation and underlain by the Pinkerton Trail Formation. Hite (1960), Hite and Cater (1972), and Hite and Buckner (1981) divided the saline section of the Paradox Formation in the evaporite basin into 29 salt cycles that onlap onto the basin shelf to the west and southwest (figure 3); Rasmussen (2010) recognizes as many as 35 cycles. Each cycle consists of a clastic-carbonate interval/salt couplet. The clastic-carbonate intervals are typically interbedded dolomite, dolomitic siltstone, silty limestone, black organic-rich shale, and anhydrite. Within the interior of the basin, a typical cycle consists of a clastic-carbonate interval or zone overlain almost entirely by halite (Morgan, 1992). The Cane Creek shale is

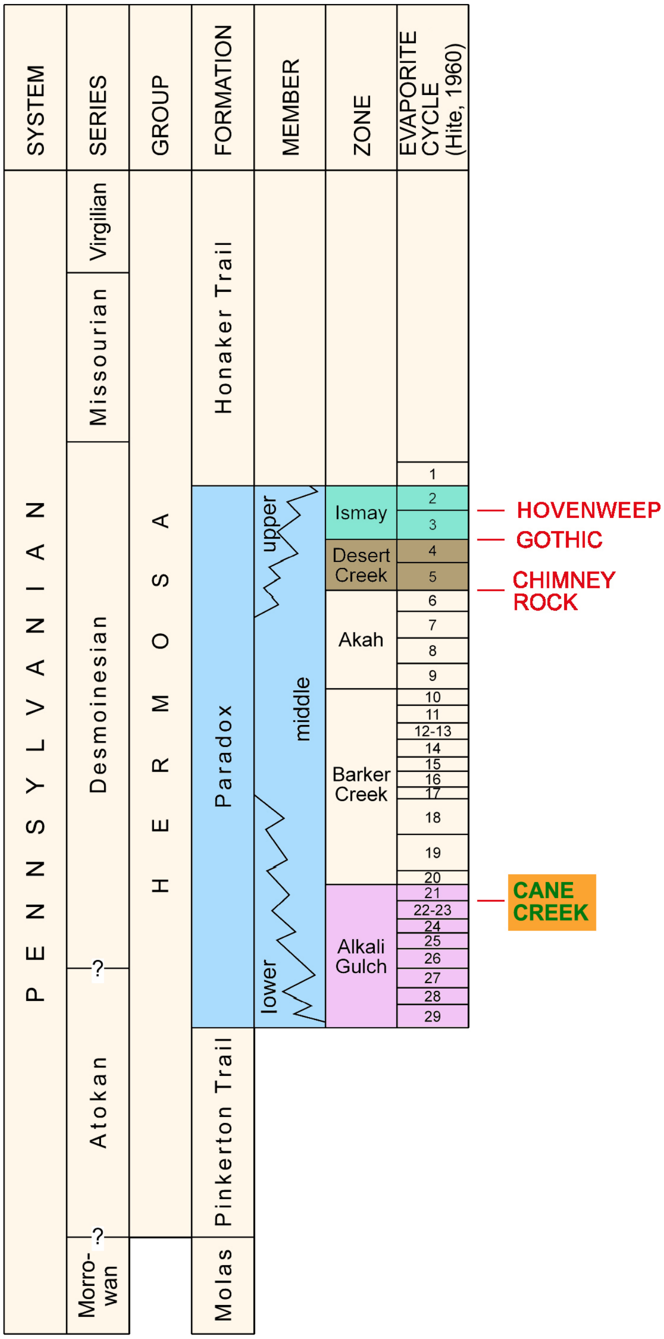

Figure 3. *Stratigraphic column of a portion of the Pennsylvanian section determined from subsurface well data in the Paradox fold and fault belt in Utah. Note the position of the Cane Creek shale, which occurs below the other potential resource play shales in the Paradox Basin (the Hovenweep, Gothic, and Chimney Rock shales). Modified from Hite (1960), Hite and Cater (1972), Reid and Berghorn (1981).*

the clastic-carbonate interval representing the basal part of cycle 21 (figure 3) and has a wide regional extent.

The Cane Creek shale generally ranges from 0 to about 200 feet (0–60 m) thick in the region. Within the main Cane Creek play "fairway" (figures 1, 2, and 4), the thickness is 60 to 170+ feet (18–52+ m). The depositional strike of the Cane Creek is north-northwest to east-southeast with a thinner section through the central part of the trend that thickens to the northeast and southwest (figure 4). However, farther to the southwest it thins where it laps onto the lower Paradox member or the Pinkerton Trail Formation (Carney and others, 2014; Morgan and others, 2014). Thickness variations are the results of diapiric salt movement, depositional thickening on the downthrown side of faults, or depositional thinning on the upthrown side of faults or over subtle, early structural highs (Morgan, 1992).

Depositional Environment

Throughout the Pennsylvanian, the Paradox Basin had subtropical, dry climatic conditions. During transgressions, open-marine waters flowed across a shallow cratonic shelf into the basin through up to four postulated marine access ways (Fetzner, 1960; Ohlen and McIntyre, 1965; Hite, 1970). Periodic decreased water circulation resulted in deposition of thick salts (halite with sporadic thinner beds of potash and magnesium salts) and anhydrite in the north and northeast part of the basin.

Cyclicity during Paradox Basin deposition was primarily controlled by glacio-eustatic sea-level fluctuations. These sea-level cycles were also influenced by (1) regional tectonic activity and basin subsidence (Baars, 1966; Baars and Stevenson, 1982), (2) proximity to basin margin (Hite, 1960; Hite and Buckner, 1981), (3) climatic variation and episodic blockage of open marine-water access ways, and (4) fluctuations in water depth and water energy (Peterson and Ohlen, 1963; Peterson, 1966; Hite and Buckner, 1981; Heckel, 1983).

The Cane Creek shale generally records a low-energy environment varying between aerobic to dysaerobic and occasionally anoxic conditions (for thin, organic-rich black shale intervals). Water depths were probably variable, ranging from below fair-weather and storm wave base for organic shales to relatively shallow to near exposure for the siltstones, sandstones, limestones, finely crystalline primary or very early diagenetic dolomites, and nodular anhydrites and other evaporites.

Petroleum Geology

Structure and Trapping Mechanisms

Structurally the Cane Creek shale is deepest in the north part of the play area, -2400 to -4000 feet (-730 to -1200 m) subsea (figure 5). The Cane Creek shallows near the southwestern edge/shelf of the basin. Oil is trapped on the crests of anticlines and along structural noses (figures 6). Salt movement along zones of weakness or areas of low confining pressure formed large folds such as the Cane Creek and Shafer anticlines (figure 7). Second-order folds caused by salt flowage are aligned directly over local bulges or pillows of Paradox salt and the overlying rocks are fractured (Lorenz and Cooper, 2009). Fracture data from oriented cores in the Cane Creek show regional, north-

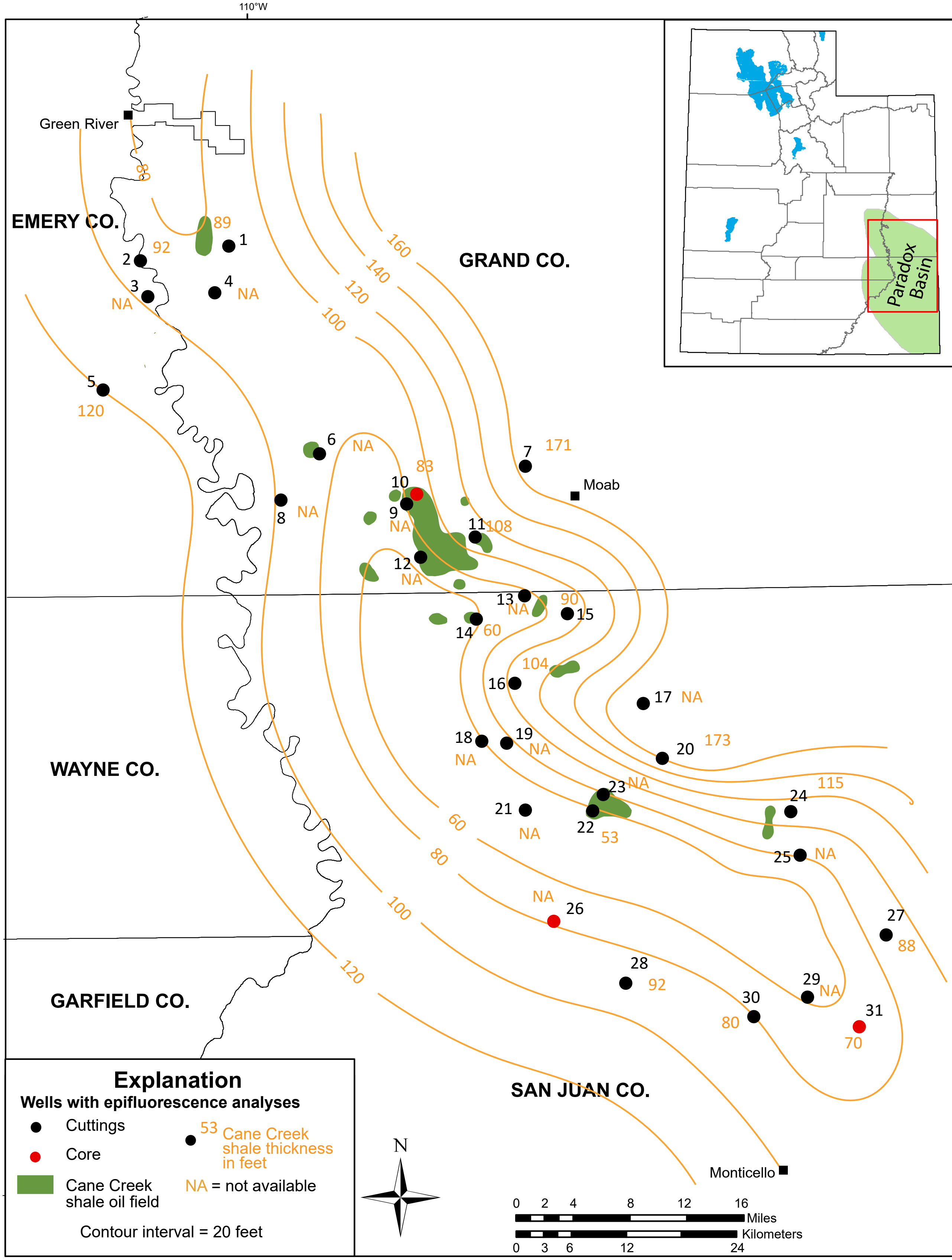

Figure 4. *General thickness of the Cane Creek shale using only wells with EF analysis. Other wells not included are scattered throughout the region or concentrated in the producing oil fields would likely result in a map showing additional thick and thin areas related to salt flowage, faulting, or depositional thinning over minor early structural highs. See table 3 for list of wells corresponding to the numbers by the black or red dots.*

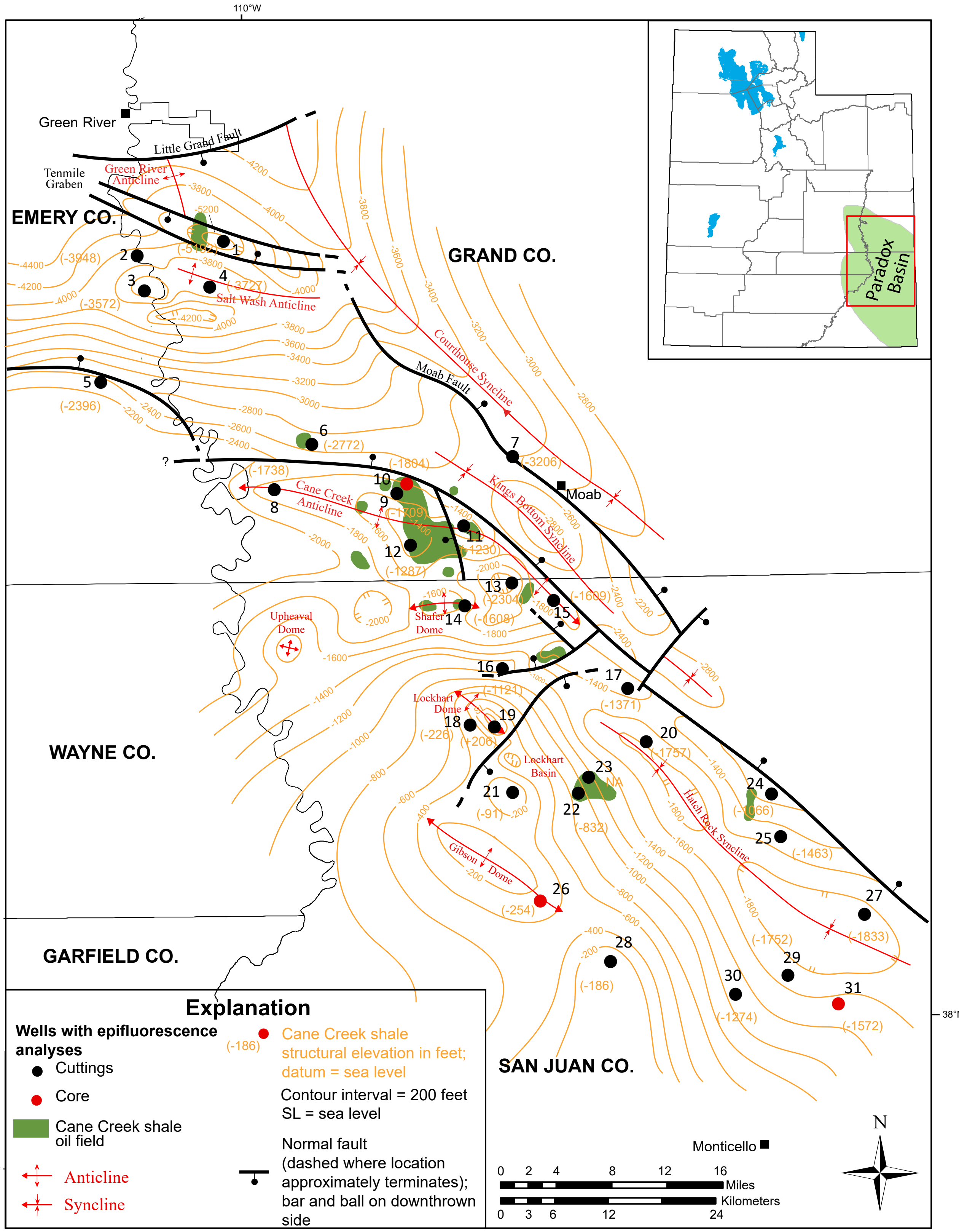

__Figure 5.__ Generalized structural map on top of the Cane Creek shale using only wells with EF analysis. Other wells not included are scattered throughout the region or concentrated in the producing oil fields and would likely result in a map with greater structural complexity. Additional faults and folds are present but are not shown given the small scale of the map. The map was created by combining published oil field reservoir maps (Peterson, 1973; Quigley, 1983; Grove and others, 1993; Morgan, 1994), and regional geologic maps and cross sections (Doelling, 2001, 2004) without the benefit of seismic data. Major folds and faults projected from surface expressions may die out in Paradox salt zones above the Cane Creek, whereas basement-involved structures may be present at the Cane Creek level where they can best be detected by seismic. See table 3 for list of wells corresponding to the numbers by the black or red dots.

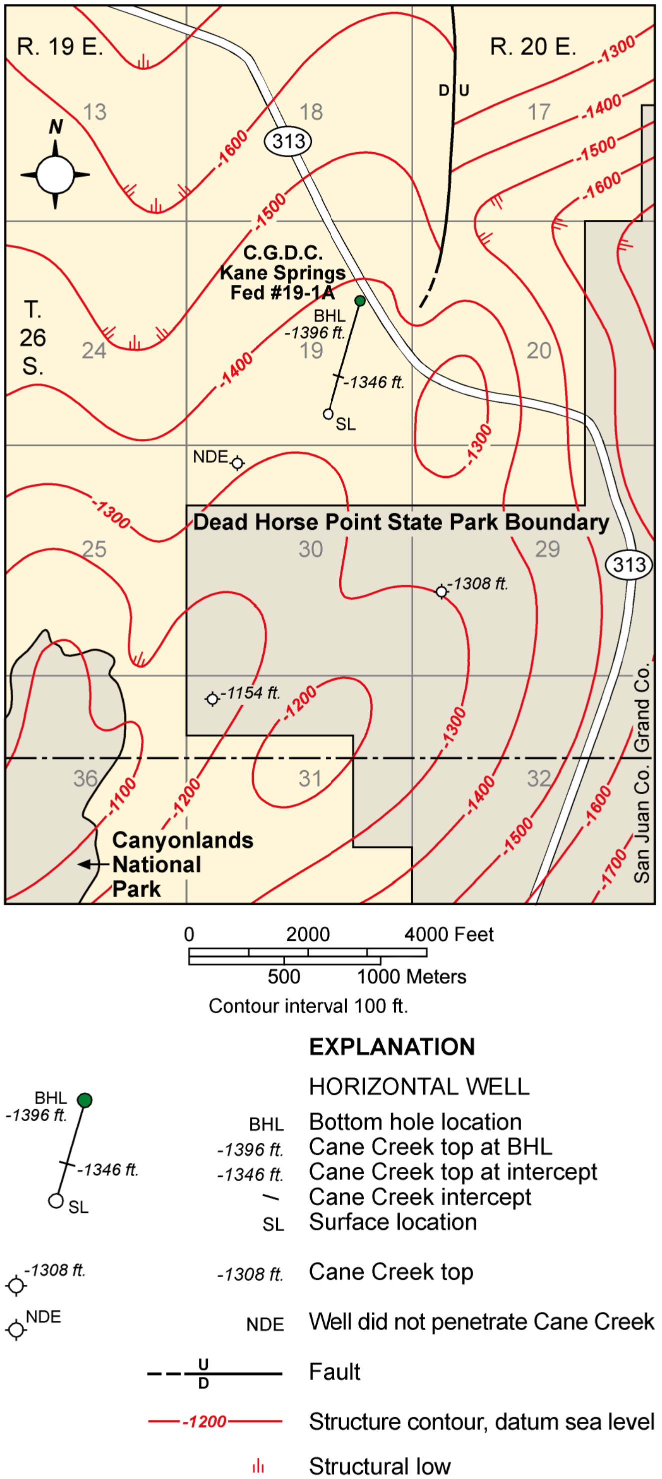

Figure 6. *Cane Creek shale structure map, Park Road oil field, Grand County, Utah. Surface location, direction, and length of horizontal well shown. After Grove and others (1993). See figure 2 for location of Park Road field.*

west to southeast and northeast to southwest, near-vertical, open, extensional fracture systems that are not significantly affected by orientations of localized folds (Grove and Rawlins, 1997; Morgan and others, 2014). Hydrocarbon production from the Cane Creek is not limited to the crests of anticlines but also from structurally high positions on upthrown fault blocks and on the downthrown side of faults. Plunging noses without apparent four-way closure produce from the Cane Creek as well as where extensive fracturing exists.

Hydrocarbon Source and Seals

Hydrocarbons in Paradox Formation reservoirs were generated from source rocks within the formation itself. Organic-rich sapropelic shale in the Cane Creek and other organic-rich shales are well-established source rocks for hydrocarbon production in the Paradox Basin (Hite and others, 1984; Nuccio and Condon, 1996). The average total organic content of the black shale in the Cane Creek is 15% with some samples containing up to 28% (Grummon, 1993; Morgan and others, 2014). Kerogens are oil-prone types I and II; maturity (based on T_{max}) and production indices from three cores studied as part of this project place the Cane Creek in the oil window (Morgan and others, 2014). The Cane Creek shale began to generate hydrocarbons within the Paradox fold and fault belt from 270 to 239 Ma (Middle Permian–Middle Triassic) (Rasmussen and Rasmussen, 2009). Expulsed hydrocarbons migrated in through dolomite, sandstone, and other porous lithologies along regional northwest-trending folds, faults, and fracture zones.

The upper and lower seals for the reservoir units in the Cane Creek shale are provided by anhydrite and halite beds. Lateral seals are permeability barriers in unfractured rock. Thus, the Cane Creek serves as the source and seal, as well as the oil reservoir rock.

Reservoir and Hydrocarbon Properties

The Cane Creek shale in the Big Flat field area (figure 2) exhibits a net-pay thickness of 25 to 30 feet (7–9 m). Dolomites and sandstones have been the main targets of horizontal drilling. Productive zones have porosity (matrix and fractures) up to 15% (Grove and others, 1993; Morgan and others, 2014). Pore types in dolomite beds are predominantly intercrystalline and microbial constructional pores, microporosity, and minor interparticle porosity. Sandstones and siltstones exhibit intergranular porosity. These lithologies can also contain significant microporosity and fracture porosity. Microfractures resulted from internal hydrocarbon generation (Fritz, 1991). Matrix permeability from Horner plots is less the 0.1 millidarcies (mD), but ranges from 39 to 400 mD with fractures (Grove and others, 1993). The larger tectonic fractures may account for most of the permeability, but the microfractures probably provide most of the fracture porosity in the reservoir. Core analysis from the productive interval in the Cane Creek No. 26-3 well (section 26, T. 25 S., R. 19 E., Salt Lake Base Line and Meridian [SLBL&M]) in Big Flat field (figure 2), Grand County, Utah, showed sandstones, argillaceous sandstones, and dolomitic argillaceous siltstones contain 5% to 12% porosity, and permeability ranging from 0.002 to 36 mD; porosity and permeability in silty dolomite was 7% and 0.004 mD, respectively (Core Laboratories, Inc., 2013).

Figure 7. Panorama of the Cane Creek anticline (middle ground); view east from Dead Horse Point State Point overlook. Note solar evaporation ponds in front of the fold and the jointed Jurassic Navajo outcrops of the Behind the Rocks area in front of the La Sal Mountains in the distance.

Initial water saturations are estimated at 10% for the fractured Cane Creek shale. The Cane Creek is highly overpressured which is probably the result of hydrocarbon generation between very impermeable upper and lower anhydrite and halite seals. Fluid gradients exceed 0.85 to 0.94 pounds per square inch (psi)/foot (19.23–21.27 kPa/m); the initial reservoir pressures average 6650 psi (45,850 kPa) (Grove and others, 1993; C.D. Morgan, Utah Geological Survey, written communication, 2015). The reservoir temperatures range from 119° to 132°F (48°–56°C) and the reservoir drive mechanism is solution gas (Grove and others, 1993).

The produced Cane Creek oils are sweet, paraffinic crudes, and amber in color. The API gravity of the oil ranges from 36° to 43°; the gas-to-oil ratio ranges from 745 to 850 cubic feet/barrel. The pour point of the crude oil ranges from 25° to 55°F (-4°–13°C) and the viscosity ranges from 7.7 to 13.3 centistokes at 104°F (40°C). The associated gas composition is 67% to 81% methane; 18% to 29% ethane, propane, and butane; 1% to 3% N_2; a trace of CO_2; and no H_2S. The gas heating value ranges from 1205 to 1471 British thermal units per cubic feet; the specific gravity ranges from 0.692 to 0.860 (Stowe, 1972; Grove and others, 1993; unpublished analyses of field oils stored at the Utah Core Research Center [UCRC]).

Drilling History, Production, and Resource Potential

The Cane Creek shale has been a target for tight-oil exploration on and off since the late 1950s. Many vertical wells have been completed in the Cane Creek, but only the Long Canyon No. 1 well (section 8, T. 26 S., R. 20 E., SLBL&M) in Long Canyon field (figure 2), Grand County, Utah, has been an economic success. Drilled in 1962, the well has produced more than 1 MMBO. The Cane Creek generated much interest in the early 1990s with the successful use of horizontal drilling. All wells drilled and completed in the Cane Creek since 1991 have used horizontal drilling techniques, with the exception of one vertical well in Greentown field, completed in 2008 (figure 2). Initial production rates generally range from 250 to 900 barrels of oil per day and around 300,000 cubic feet of gas per day.

Eighteen fields have produced over 7.8 MMBO and associated gas of about 7.9 BCF from the Cane Creek shale as of January 1, 2016 (figure 2; tables 1 and 2); associated water production is over 1.4 million barrels (Stowe, 1972; Utah Division of Oil, Gas and Mining, 2016). Between 1959 and 1982, 10 Cane Creek discoveries were made in the Paradox Basin. Cumulative production from these fields is about 1.4 MMBO and over 3.3 BCFG, all from vertical wells. However, seven of these fields are now abandoned and three are shut-in (table 1). Currently, eight active fields produce from the Cane Creek, seven have horizontal wells. Cumulative oil production as of January 1, 2016, from the horizontal wells is over 6.3 MMBO and 4.3 BCFG; 30 active horizontal wells exist in these fields (table 2) (Utah Division of Oil, Gas and Mining, 2016). The majority of production is from Big Flat field and the surrounding area (figure 2).

Estimated recovery for successful Cane Creek horizontal wells is 250,000 to 1 MMBO per well (IHS Inc., 2013). The U.S. Geological Survey (2012), Whidden and others (2014), and Anna and others (2014) re-assessed the undiscovered oil resource in the Cane Creek at 103 MMBO at a 95% confidence level and 198 MMBO at a 50% confidence level.

EPIFLUORESCENCE

Epifluorescence microscopy is a technique that has been used successfully in recent years to provide additional information on grain and textural recognition, diagenesis, pore shapes and sizes, fracture recognition, and organic matter (including "live" hydrocarbons) within sedimentary rocks. It is a rapid, non-destructive procedure that requires a high-quality petro-

Table 1. *Cumulative oil and gas production from fields having vertical wells completed in the Cane Creek shale. Data from Stowe (1972) and the Utah Division of Oil, Gas and Mining as of January 1, 2016. See figure 2 for field locations; all well locations are SLBL&M.*

Field Name and/or Well Name and Location	Completion Date	Current Status	Cumulative Production Oil* Gas†
Greentown Federal 28-11 Section 28, T. 22 S., R. 17 E.	2008	Producing‡	71,535 BO 0.27 BCFG
Bartlett Flat	1961	Abandoned 1965	39,393 BO 0.02 BCFG
Gold Bar Gold Bar 1 Section 29, T. 25 S., R. 20 E.	1982	Abandoned 1984	13,393 BO 0.01 BCFG
Unnamed Mathew Federal 1 Section 4, T. 26 S., R. 20 E.	1981	Abandoned 1982	1343 BO 0 BCFG
Unnamed Skyline 1 Section 5, T. 26 S., R. 20 E.	1982	Abandoned 1982	675 BO 0.001 BCFG
Unnamed Skyline 8-44 Section 8, T. 26 S., R. 20 E.	1976	Abandoned 1976	507 BO 0 BCFG
Long Canyon	1962	Shut-in	1,152,150 BO 1.2 BCFG
Kane Creek	1959	Abandoned 1969	1887 BO 0.03 BCFG
Shafer Canyon	1962	Abandoned 1967	67,556 BO 0.06 BCFG
Lion Mesa	1980	Shut-in	1904 BO 0 BCFG
Wilson Canyon	1968	Shut-in	126,918 BO 2.0 BCFG
TOTAL			1,477,261 BO 3.6 BCFG

* BO = barrels of oil
† BCFG = billion cubic feet of gas
‡ comingled with cycle 19 in the Paradox Formation

graphic (polarizing) microscope equipped with reflected light capabilities as well as an Hg-vapor light source and appropriate filters. The basic principles and equipment for EF were largely developed in the 1960s and 1970s for applications in coal petrology and palynology (van Gijzel, 1967; Teichmuller and Wolf, 1977). All applications depend upon the emission of light (by a material capable of producing fluorescence) that continues only during absorption of the excitation-generating light beam (Rost, 1992; Scholle and Ulmer-Scholle, 2003).

Epifluorescence techniques have been used within industry and research for three objectives. Firstly, EF microscopy has been used extensively for enhancing petrographic observations, including the recognition of depositional and diagenetic fabrics within recrystallized limestone and massive dolomite (Dravis and Yurewicz, 1985; Cercone and Pedone, 1987; Dravis, 1991; LaFlamme, 1992). Secondly, the study of pore structures, microfractures, and microporosity within both carbonates and sandstones has been greatly facilitated by impregnating these voids with epoxy spiked with fluorescing dyes (Yanguas and Dravis, 1985; Gies, 1987; Cather and others, 1989a, 1989b; Soeder, 1990; and Dravis, 1991). Thirdly, the evaluation of "oil shows" (Eby and Hager, 1986; Kirby and Tinker, 1992) and determination of the gravity or type cements and minerals has been facilitated by EF microscopy (Burruss, 1981, 1991; Burruss and others, 1986; Guihaumou and others, 1990; LaVoie and others, 2001). The third objective, i.e., "oil show" analysis, is the principal goal of this study.

Previous Work

We know of no published use of EF microscope techniques on the Cane Creek shale of the Paradox Basin. However, applications to carbonate reservoirs include Eby and Hager (1986) who studied a Permian Basin carbonate field in West Texas;

Table 2. *Cumulative oil and gas production from fields having horizontal wells completed in the Cane Creek shale. Data from the Utah Division of Oil, Gas and Mining as of January 1, 2016. See figure 2 for field locations; all well locations are SLBL&M.*

Field Name or Well Name and Location	Completion Date	Active Horizontal Wells	Current Status	Cumulative Production Oil* Gas†
Big Flat	1991	21	Producing	5,034,861 BO 3.4 BCFG
Park Road	1991	2	Producing	489,564 BO 0.2 BCFG
Hell Roaring Field	1992	1	Producing	659,883 BO 0.6 BCFG
Hatch Point	2009	2	Producing	71,836 BO 0.04 BCFG
Unnamed Two Fer 26-30 Section 26, T. 26 S., R. 20 E.	2009	1	Producing	11,028 BO 0 BCFG
Unnamed La Sal 29-28 Section 29, T. 29 S., R. 23 E.	2011	1	Shut-in	5458 BO 0.01 BCFG
Cane Creek	2014	2	Producing	57,582 BO 0.03 BCFG
TOTAL		30		6,330,212 BO 4.3 BCFG

* BO = barrels of oil
† BCFG = billion cubic feet of gas

case studies documented by Dravis (1988, 1992) on the Upper Jurassic Haynesville limestones, East Texas and Devonian Upper Elk Point dolomites, western Canada; a regional "oil show" analysis within the Devonian Keg River/Winnipegosis petroleum system in Alberta (Kirby and Tinker, 1992); and more recently an evaluation of the Mississippian Leadville Limestone in the Paradox Basin by Eby and others (2008). These studies provided justifications to apply EF petrography to the Cane Creek shale reservoir rocks.

Methods

Epifluorescence petrography for this project used incident (reflected) blue-light fluorescence microscopy employing the general procedures outlined by Dravis and Yurewicz (1985). Ultraviolet (UV) fluorescence did not effectively add any textural or pore structure information that could not otherwise be seen under blue-light excitation, even though some researchers use UV fluorescence for evaluating fluid inclusions and compositional zoning within dolomite crystals (Scholle and Ulmer-Scholle, 2003). Fluorescence data and observations collected for this study used a Jena (now part of Carl Zeiss) research-grade combination polarizing-reflected light microscope equipped with a high-pressure mercury vapor lamp for EF excitation, a Zeiss IIIRS epifluorescence nosepiece, and a film imaging system (figure 8). Magnification ranges for examination and image-documentation were between about 130 and 320X. The EF optical configuration used is similar to that shown in figure 9.

The light pathways and mechanics of the EF used in this study have been generally outlined by Soeder (1990). As described by Burruss (1991):

> These excitation wavelengths are reflected to the microscope objective and sample by a dichroic beamsplitter which has a dielectric coating that reflects a specific short wavelength range. Fluorescence emission and reflected short wavelength excitation light is collected by the objective. The dichroic beamsplitter transmits the long wavelength fluorescence emission, but reflects the short wavelengths back toward the light source. The fluorescence emission passes through a barrier filter that removes any remaining short wavelength excitation light.

Blue light (about 420 to 490 nanometer [nm] exciter filter/520 nm barrier filter) was used to excite the cuttings and core-chip samples, and uncovered thin sections. Broadband, blue-light EF was found to be the most helpful in observational work on dolomites, although some workers report applications using UV light (330 to 380 nm exciter filter/420 nm barrier filter) or narrow-band, blue-violet light (400 to 440 nm exciter filter/480 nm barrier filter). Finally, the greater depth of investigation into a sample by the reflected fluorescence technique than by transmitted polarized light or other forms of reflected light makes it possible to better evaluate "live oil shows" in the samples as well as resolve grain boundary and compositional features that are normally not appreciated in cutting or thin-section petrography.

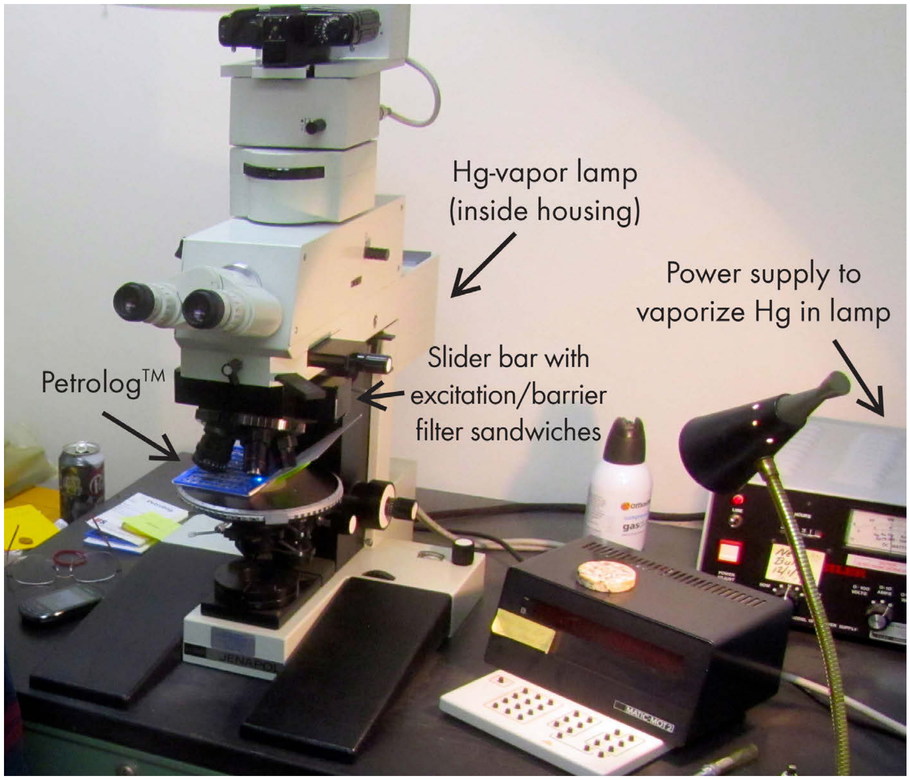

Figure 8. *Microscope equipment used for this study.*

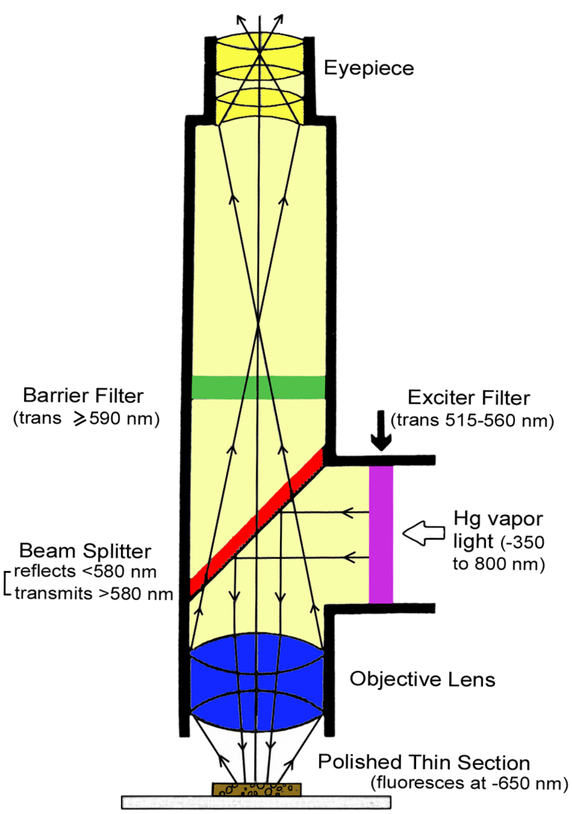

Figure 9. *Generalized optical configuration of a microscope for observing fluorescence under incident light (nm = nanometer). Modified from Soeder, 1990. AAPG© 1990, reprinted by permission of the American Association of Petroleum Geologists whose permission is required for further use.*

Sampling, Examination, and Evaluation

Cuttings or cores (as well as a few selected thin sections) from wells penetrating the Cane Creek shale were obtained from the collection at the UCRC and the Texas Bureau of Economic Geology core repository (one well – Gibson Dome) (table 3). Cuttings were examined under a binocular microscope and representative samples of dolomites, limestones, sandstones, siltstones, and shales were selected from various intervals over the Cane Creek section (see figure 10, table 3, and appendices A and B): usually 10 samples (in a few wells, less than 10 good quality samples were available) per cuttings sample interval, typically every 10 feet (3 m), from each well. The cuttings or core chips were placed on Petrologs™, small plastic, self-adhesive compartmentalized cuttings storage units, for EF examination (figure 11). Thus, sample collection and preparation is relatively inexpensive; however, it can be time consuming depending on the quality and number of samples.

Examination of each sample (cutting or core chip) often included the use of image-photography and a petrographic description under EF (see appendix C). Photomicrography of any "live oil" fluorescence attributes used high-speed film (ISO 800 and 1600). Since the image brightness is directly proportional to magnification, we obtained the best images at relatively high magnifications (such as greater than 100X). Image brightness can be affected by how the samples are stored, under what conditions, etc. Thus, fluorescence can decrease its intensity through time and environment of stor-

Table 3. *Wells containing cuttings or core chips in the Cane Creek shale evaluated using epifluorescence techniques. See figure 10 for well number locations.*

Well #	Well Name	Location			County	Well Type	Interval (ft)	Wellbore	N
		Section	Township	Range					
1	Salt Wash Unit 22-34	34	22S	17E	Grand	Dry hole	9420−9500	V	80
2	Jakey's Ridge 12-3	3	23S	16E	Emery	Dry hole	7990−8090	V	97
3	Jakey's Ridge 34-15	15	23S	16E	Emery	Dry hole	7640−7740	V	100
4	Salt Wash 1-16	16	23S	17E	Grand	Dry hole	8250−8330	V	71
5	Gruvers Mesa 1	19	24S	16E	Emery	Dry hole	7185−7290	V	100
6	Kane Springs Fed 10-1	10	25S	18E	Grand	Producing oil well	8890−8940	V	49
7	Utah 2	18	25S	21E	Grand	Dry hole	7580−7730	V	108
8	Fed Bowknot 1	30	25S	18E	Grand	Dry hole	6940−7020	V	71
9	Kane Springs Fed 25-19-34-1	34	25S	19E	Grand	Producing oil well	7550−7770	H	149
10	Cane Creek Unit 26-3	26	25S	19E	Grand	Producing oil well	7389−7470	V	197
11	Long Canyon 1	9	26S	20E	Grand	Producing oil well	7020−7135	V	39
12	Mineral Canyon U 1-14	14	26S	19E	Grand	PA oil well	7330−7420	V	65
13	Federal 1-X	36	26S	20E	San Juan	Dry hole	6520−6685	V	43
14	Featherstone-Federal 9-1	9	27S	20E	San Juan	Dry hole	5790−5895	V	100
15	West Bridger Jack U 3	3	27S	21E	San Juan	Dry hole	5900−5970	V	68
16	Cane Creek State 1-36	36	27S	20E	San Juan	Dry hole	7000−7100	V	90
17	Red Rock Unit 1	9	28S	22E	San Juan	Dry hole	6790−6910	V	104
18	Lockhart-Fed 1	22	28S	20E	San Juan	Dry hole	4765−4820	V	94
19	USA Lockhart 1	23	28S	20E	San Juan	Dry hole	4380−4430	V	46
20	Government B-1	34	28S	22E	San Juan	Dry hole	7535−7720	V	156
21	Horsehead Unit 1	18	29S	21E	San Juan	Dry hole	6290−6390	V	100
22	Hatch Point 1	14	29S	21E	San Juan	Producing oil well	7220−7270	V	38
23	Threemile 12-7	12	29S	21E	San Juan	Producing oil well	7530−7690	H	38
24	La Sal USA 1	19	29S	24E	San Juan	Dry hole	7580−7700	V	106
25	Lisbon D232	32	29.5S	24E	San Juan	Dry hole	7820−7870	V	60
26	Gibson Dome	21	30S	21E	San Juan	Dry hole	5220−5310	V	89
27	Little Valley 2	29	30S	25E	San Juan	Dry hole	8370−8410	V	35
28	Hart Point Fed 1	8	31S	22E	San Juan	Dry hole	6740−6830	V	77
29	Winchester 21-1H	21	31S	24E	San Juan	Dry hole	7740−7840	H	90
30	Church Rock Unit 1	26	31S	23E	San Juan	Dry hole	7460−7510	V	48
31	Cisco State 36-13	36	31S	24E	San Juan	Dry hole	7589−7649	V	133

N = number of samples
V = vertical
H = horizontal

age. However, we choose not to rate these factors. Low-power fluorescence is often too dim to effectively record on film. These techniques are applicable to clean or broken cuttings surfaces as well as uncovered thin sections from both core and core chips. Samples of well cuttings or core chips selected for image-documentation under EF were also photographed using a binocular microscope (appendix C).

Approximately 2650 cuttings samples and core chips were evaluated from 31 wells penetrating the Cane Creek shale throughout the region (figure 10 and table 3; see appendices A and B for EF evaluation and detailed descriptions). Samples from three cores (a producer and two dry holes) provided a template for selection of the drill cuttings and calibration of EF shows. The 31 study wells include 7 producers, including the Long Canyon No. 1 well discussed previously. The binocular microscope study of the samples accompanied the EF work. We described carbonate fabrics according to Dunham's (1962) and Embry and Klovan's (1971) classification schemes. We defined pore types and pore systems using Choquette and Pray's (1970) classification.

Epifluorescence petrography makes it possible to clearly identify hydrocarbon shows in Cane Creek cuttings and core chips. A note of caution that "newer" cores can have higher fluorescence than "older" cores, especially in the first

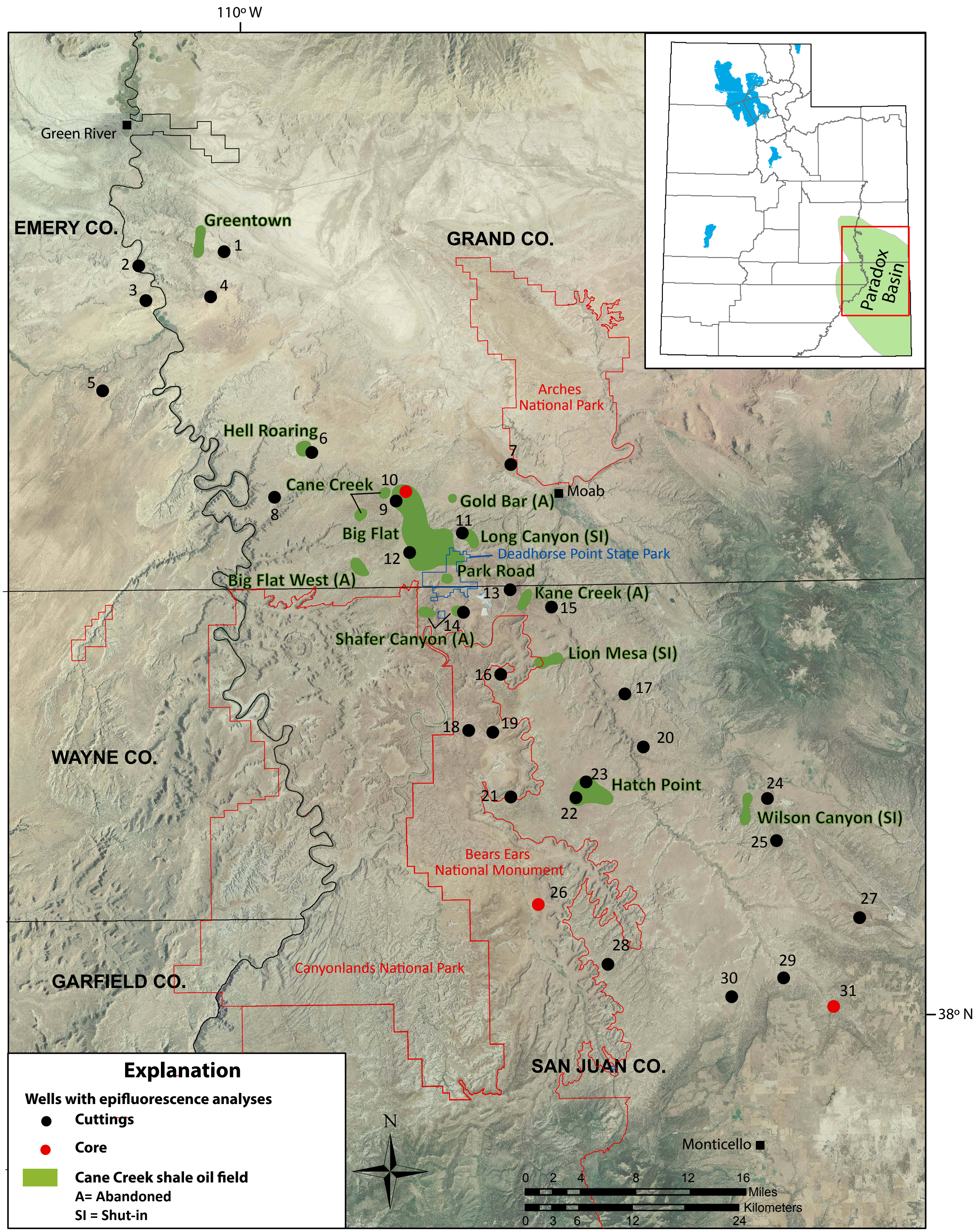

Figure 10. *Wells containing cuttings or core chips in the Cane Creek shale evaluated using epifluorescence techniques. See table 3 for list of wells corresponding to the numbers by the black or red dots.*

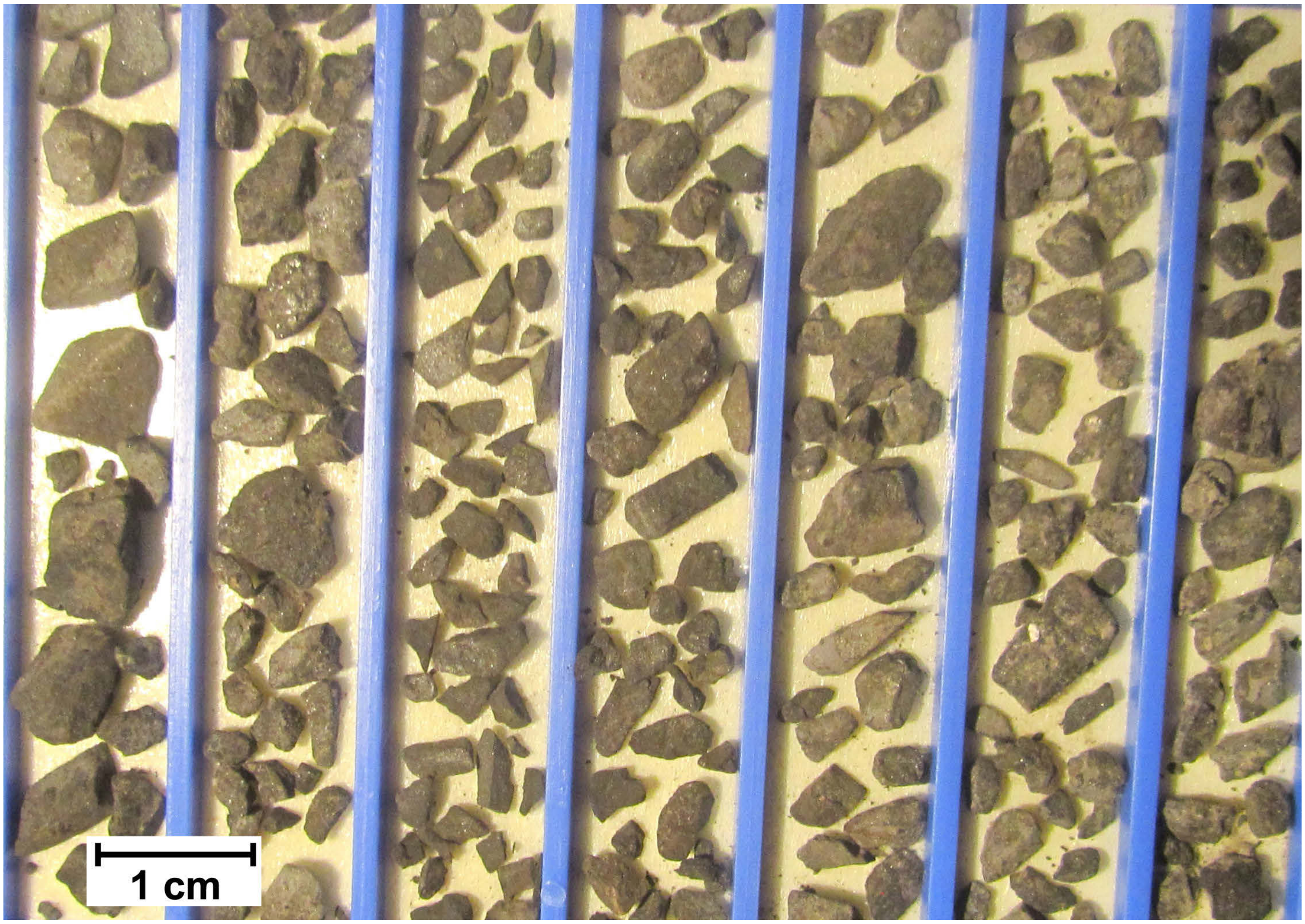

Figure 11. *Example of handpicked Cane Creek shale cuttings samples selected from various depths from 7770 to 7870 feet, Lisbon No. D232 well (well #25 on figure 10; NE1/4NE1/4 section 32, T. 29.5 S., R. 24 E., SLBL&M, Grand County, Utah, placed on Petrologs™ for epifluorescence examination.*

few months after coring. We developed and applied a new qualitative visual rating scale (a range and average) based on EF visual evaluation, but not quantitative measurements with samples of equal quality, to the group of cuttings or core chips (when available as well as a few uncovered thin sections) from each depth in each well (figure 12, table 4, and appendices A and B). The photomicrographs of EF images shown on figure 12 can be matched to the EF rating scale and general interpretation listed in table 4. Using the qualitative visual rating scale, a variety of EF readings from each well were plotted and mapped to aid in the identification of hydrocarbon "sweet spots" in the Cane Creek shale.

CHARACTERISTICS OF CANE CREEK INTERVALS

The Cane Creek shale is overlain and generally underlain by anhydrite and halite. It is divided into three intervals in descending order: A, B, and C (figure 13). Each interval has a fairly distinct wireline well log characteristic, especially the gamma-ray profile, which allows good correlations through the region.

When cores are available, like those at the UCRC, the data on wireline logs can be matched directly to the cored lithologies from the well. These logs then become templates to identify Cane Creek lithology, reservoir properties, and other core-derived information for the A, B, and C interval in wells that have no cores (figure 14). However, good quality Cane Creek cuttings also provide a wealth of data as demonstrated by this study. These data can be tied to wireline logs as well. Finally, the cuttings and core chips from the Cane Creek provide means to characterize the lithology and pore types found in the A, B, and C intervals, and determine oil shows through EF as described in the sections that follow.

Core-Based Lithology, Porosity Types, and Fracturing

In the Cane Creek shale (figure 14), the A interval is generally composed of alternating thin beds (1 to 4 feet [0.3–1.2 m] thick) of silty to shaly carbonates (both limestone and dolomite); anhydritic dolomites; interbedded, gray to black organic-rich shale; and laminated, mottled, or nodular anhydrite. Other lithologies include dolomitic siltstone and mudstone. Sedimentary features include thin, horizontal laminations

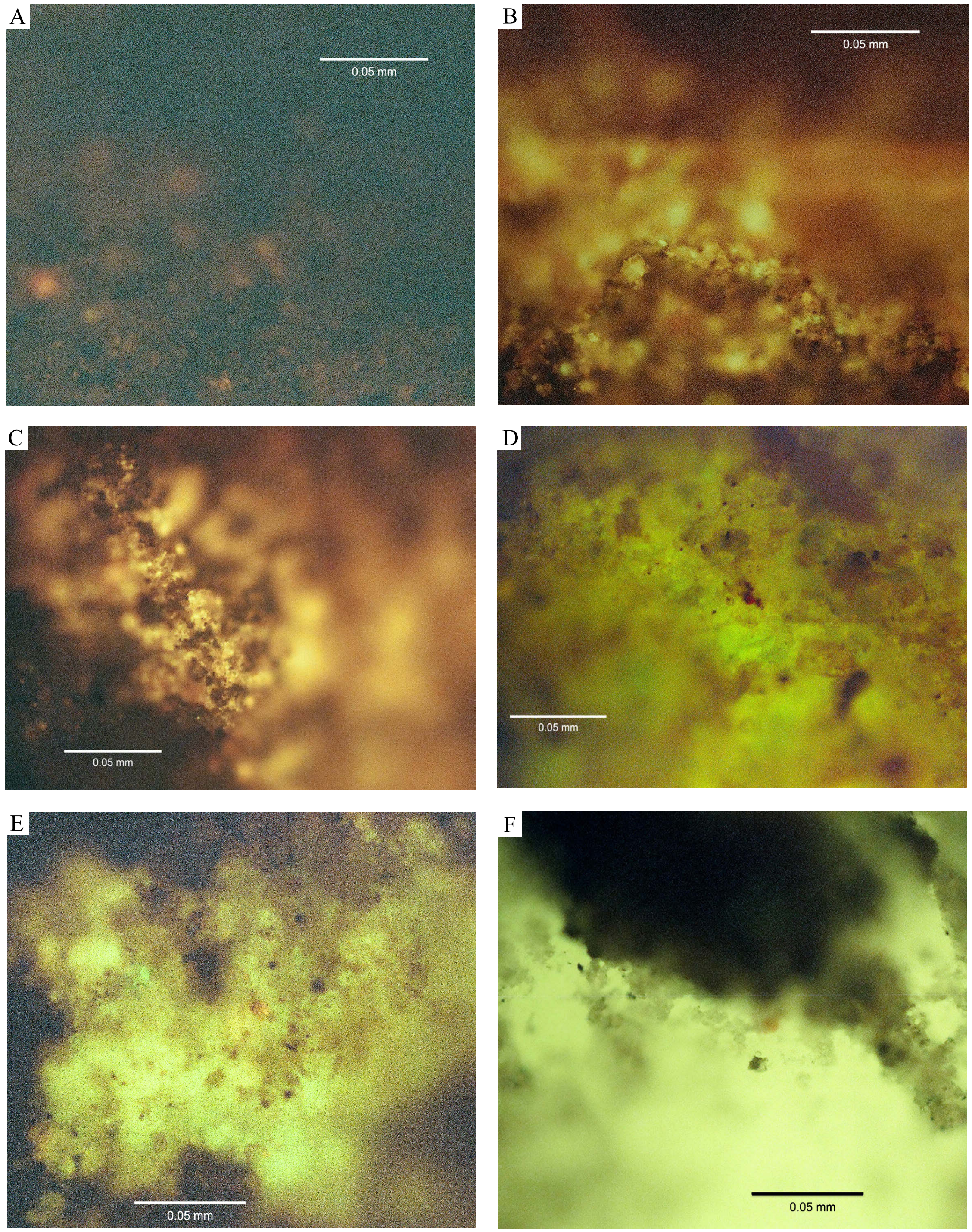

Figure 12. *Photomicrographs showing examples of visually rated epifluorescence in the Cane Creek shale play; these images can be matched to the qualitative visual epifluorescence rating scale and general interpretation listed on table 4.* ***A.*** *Almost no fluorescence (rated at 0.7) in a silty to dolomitic shale from the 6290–6300 foot sample in the Horsehead Unit No. 1 well (well #21; NW1/4SW1/4 section 18, T. 29 S., R. 21 E., SLBL&M, San Juan County).* ***B.*** *Very weak fluorescence (rated at 1.3) in a microcrystalline dolomitic mudstone from the 6290–6300 foot sample from the Horsehead Unit No. 1 well. Note the crinkly lamina that could be microbial in origin.* ***C.*** *Weak and spotty fluorescence (rated at 1.5) in a microcrystalline and microporous dolomitic mudstone from the 7380–90 foot sample in the Mineral Canyon No. 1-14 well (well #12; SW1/4SE1/4 section 14, T. 26 S., R. 19 E., SLBL&M, Grand County).* ***D.*** *Moderate and continuous fluorescence (rated at 2.4) in rhombic clusters of crystalline dolomite within a peloidal(?) grainstone from the 7260–70 foot sample in the Hatch Point No. 1 well (well #23; NE1/4SE1/4 section 14, T. 29 S., R. 21 E., SLBL&M, San Juan County).* ***E.*** *Moderately bright fluorescence (rated at 2.5) in a microcrystalline dolomite with possible organic or microbial structures from the 4800–10 foot sample in the Lockhart Federal No. 1 well (well #18; SW1/4SW1/4 section 22, T. 28 S., R. 20 E., SLBL&M, San Juan County).* ***F.*** *Moderately bright fluorescence (rated at 3.0) in a microlaminated (microbial?), medium crystalline dolomite from the 7600–10 foot sample in the Kane Springs Federal No. 25-19-34-1 well (well #9; NW1/4SE1/4 section 34, T. 25 S., R. 19 E., SLBL&M, Grand County).*

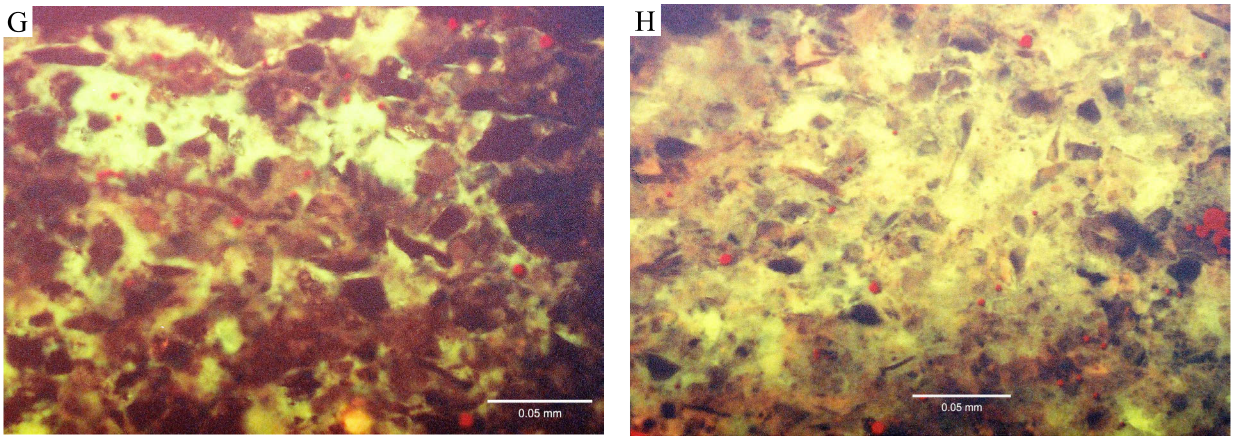

Figure 12 continued. G. *Moderately bright fluorescence (rated at 3.0) in a silty and dolomitic peloidal grainstone/packstone imaged in a polished uncovered thin section from conventional core at 7439 feet from the Cane Creek Unit No. 26-3 well (well #10; NE1/4SW1/4 section 26, T. 25 S., R. 19 E., SLBL&M, Grand County). Note the connected bands of bright yellow oil fluorescence. The rare reddish spots are iron-rich, and probably micro-pyrite.* ***H.*** *Very bright and continuous fluorescence (rated at 3.6) in a very silty microcrystalline dolomite mudstone imaged in a polished uncovered thin section from conventional core at 7430.9 feet from the Cane Creek Unit No. 26-3 well. The reddish spots are iron-rich, and probably micro-pyrite. See figure 10 for well number locations.*

Table 4. *Key to epifluorescence qualitative visual rating scale. See photomicrographs shown on figure 12 for examples of epifluorescence at the various visual ratings listed in the table below.*

Rating	Generalized Interpretation
0–1.0	No Fluorescence: not capable of oil production. May be wet, if not a gas-bearing interval. See figure 12A.
1.0–1.5	Very Weak Fluorescence: an "oil" show. Indicative of minor oil in the system, but not capable of production. Some dull or weak fluorescence may exist in a wet zone (especially if there is "speckled" fluorescence) or in a mixed oil/water zone. See figure 12B.
1.5–2.0	Weak/Spotty Fluorescence: a good "oil" show. Indicative of oil in the system, but probably not capable of production. See figure 12C.
2.0–2.5	Moderate Fluorescence: a good indication of oil within this interval. Probably capable of some oil production if there is adequate porosity and permeability/fracturing. See figure 12D.
2.5–3.0	Moderately Bright Fluorescence: a good to very good indication of movable oil within this interval. May be capable of some oil production if there is adequate porosity and permeability/fracturing. See figure 12E.
3.0–3.5	Bright Fluorescence: a very good to excellent indication of oil within this interval. Should be capable of oil production if there is adequate porosity and permeability. See figures 12F and 12G.
3.5–4.0	Very Bright, Intense Fluorescence: also an excellent to the best indication of oil within this interval. However, some very bright fluorescence may indicate very tight oil-bearing rocks or mature oil-generating source rocks. See figure 12H.

(possibly microbial) and evidence of bioturbation or haloturbation; some rip-up clasts are found near the base of the interval. The A interval, with its abundant anhydrite, represents the main seal for the reservoir rocks in the B interval below.

The B interval, the primary oil reservoir unit, is composed of interbedded thin gray and black organic-rich shale, shaly, muddy, silty or sandy dolomite, finely crystalline dolomite, dolomitic mudstone, limestone, thin dolomitic siltstone, and dolomitic sandstone (figures 14 and 15). Some dolomite beds contain peloids and minor mottled anhydrite. Sandstone is very fine grained consisting of quartz and feldspar cemented with calcite or dolomite. Sedimentary features include thin, horizontal to wavy laminations or zones of bioturbation or haloturbation. Rip-up clasts are found near the base of a few sandstones or at the top of dolomites. Typically the B interval is naturally fractured.

The C interval is composed of interbedded shaly to silty dolomite; dolomite containing mottled anhydrite; dolomitic sandstone to siltstone; anhydrite; and a few thin, black, organic-rich shale beds. The sandstones are very fine grained, showing massive to some horizontal bedding. Other lithologies show thin bedding, fine lamination, or possible wavy beds; anhydrite is bedded to massive. Several units show bioturbation or haloturbation. The C interval represents the lower seal for the reservoir rocks in the B interval above. The anhydrite and low-permeability dolomite helps prevent fracture communication with underlying halite beds (Morgan and others, 2014).

The dolomites in Cane Creek A, B, and C intervals all display well-developed intercrystalline porosity, microporosity, and microbial constructional (tubular) pores. Clusters of micro-rhombic dolomites typically contain intercrystalline pores. A few vugs or molds and minor interparticle porosity are

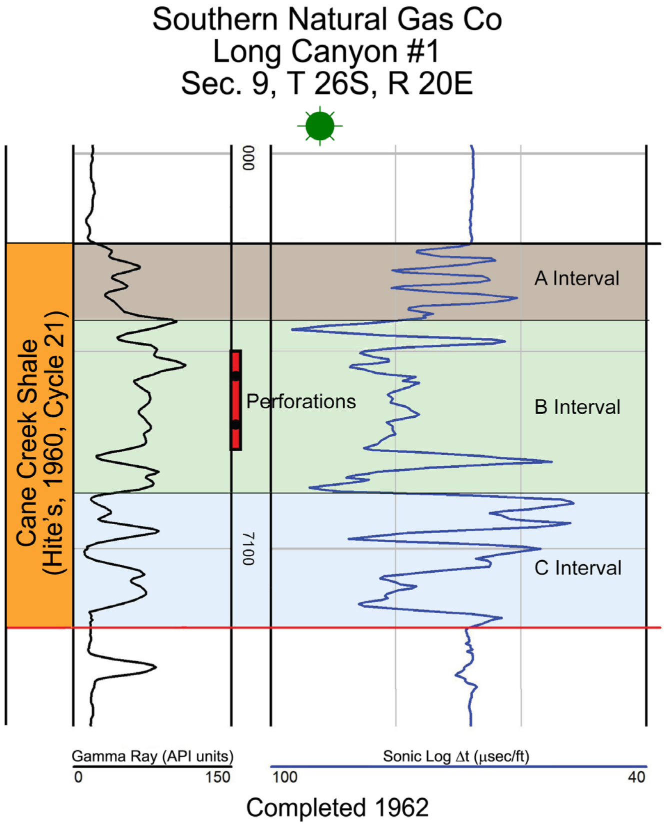

Figure 13. *Typical gamma-ray–sonic log of the Cane Creek shale, Long Canyon field, Grand County, Utah, showing the division of the Cane Creek shale into "A," "B," and "C" intervals. Cumulative production from a vertical borehole in this well (to January 1, 2016) = 1,125,446 barrels of oil, 1.16 BCFG, and 571,991 barrels of water (Utah Division of Oil, Gas and Mining, 2016). See figure 2 for location of Long Canyon field.*

preserved. Pores may be lined with secondary calcite or dolomite crystals, or plugged with anhydrite. Brittle sandstone and siltstone beds typically contain fracture porosity. They also exhibit intergranular porosity as well as microporosity.

Both vertical and subvertical fractures are common; some can be classified as microfractures and microstylolites. Horizontal to subhorizontal fractures are sparse. Zones of brecciation (including autobrecciation) are commonly present, especially near the base of the intervals or above anhydrite beds; a few slickensides are also present. Fractures are typically sealed with halite, anhydrite, clay, and calcite whereas some fractures remain open (Morgan and others, 2014); bitumen-lined fractures also occur. Microfractures contain dolomite fill and sulfide minerals. Fractures trend northeast-southwest (Morgan and others, 2014).

Principal Rock Types for Epifluorescence Evaluation of Cuttings and Cores

The principal rock types used for our epifluorescence evaluation in cuttings and core chips collected from the A, B, and C intervals in the Cane Creek shale are (1) dolomitic sandstone and siltstone, (2) microcrystalline dolomite mudstone, (3) dolomitized peloidal grainstone, (4) dolomitized peloidal/coated grain grainstone/packstone, (5) dolomitized microbialites, (6) dolomitized oncolitic/pisolitic rudstone, and (7) dolomitic to silty shale (figure 16; see appendices B and C for complete petrographic descriptions; however, diagenesis and depositional environments were not part of this study). Some of these rock types are more prevalent in one or two of the Cane Creek intervals. For example, dolomitic sandstone and siltstone, peloidal grainstone/packstone, and dolomitized microbialites are most common in the B interval. Finely crystalline dolomites, limestones, siltstones, and sandstones are the best samples for qualitative EF analysis (most of our samples were finely crystalline dolomites), especially if they are porous, whereas black shales are generally "dead" or lack visible EF.

A Interval

Cuttings and core chip samples from the A interval consist of (1) microcrystalline and fine to medium crystalline dolomite, (2) silty to argillaceous dolomite, (3) dolomitic mudstone (figures 12B and 16A), (4) black organic-rich shale, silty shale, silty dolomitic shale (figure 16A), and dolomitic shale, (5) siltstone, dolomitic siltstone, and argillaceous siltstone, and (6) anhydrite and salt. These lithologies can include patches of anhydrite and argillaceous material or clusters of dolomite crystals in the matrix. Dolomitized carbonate fabrics range from grainstones to mudstones, and include some framestones and boundstones as well. Packstones and grainstones are sporadically fossiliferous containing bryozoans or other fossil remains. Interbedding of various lithologies or carbonate fabrics is common. Laminations in boundstones may be microbial in origin with tubular structures. Siltstone is typically poorly sorted.

B Interval

Cuttings and core chip samples from the productive B interval consist of (1) microcrystalline (figure 12C) and silty microcrystalline dolomite (figure 12H), (2) fine- to medium-crystalline dolomite, (3) silty to black argillaceous dolomite, (4) black organic-rich shale, silty shale, silty dolomitic shale, and dolomitic shale, (5) siltstone and dolomitic siltstone, (6) dolomitic sandstone (figure 16A), (7) silty limestone, and (8) anhydrite and salt. Some dolomite cuttings appear to be organic rich. Patches of coarse-grained dolomite display rhombic crystals. Carbonate fabrics, most of which are dolomitized, range from grainstones to mudstones. Skeletal grainstones contain bryozoans and possible ostracods; some packstones and wackestones are also fossiliferous. Carbonate textural components include peloids (figure 12G), ooids, and coated grains. Well-developed microbialites (figure 12F) are relatively common displaying microbial laminations, tubular microstructures with possible construction pores, and other diagnostic textures. Microbial constructional pores, where present and well developed, likely enhance reservoir quality

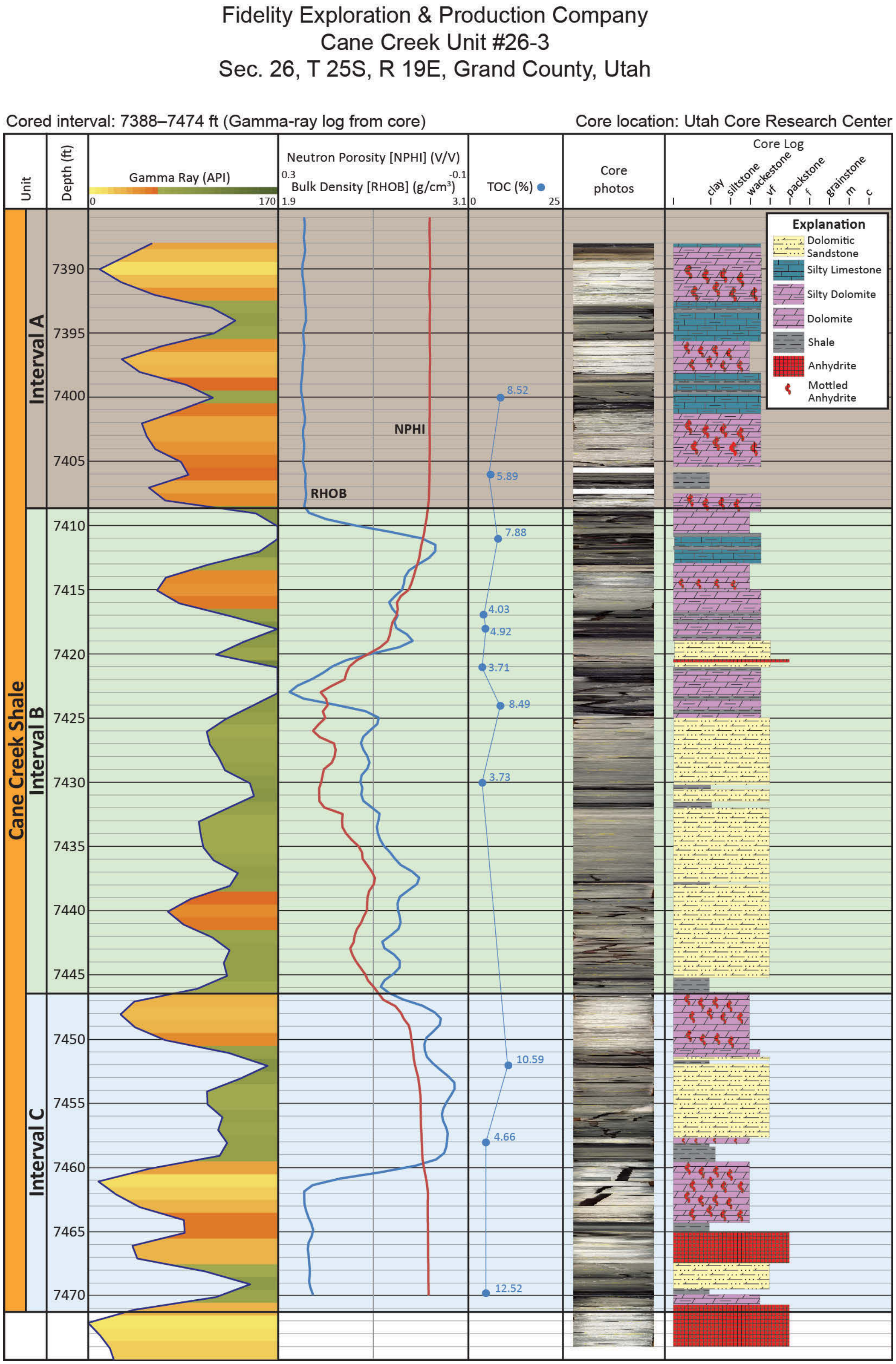

Figure 14. *Gamma-ray–neutron porosity–bulk density log profiles as well as total organic carbon (TOC), tied to lithology data from a recent Cane Creek shale core in Big Flat field, Grand County, Utah. Note the variations between the log and lithologic characteristics of the A, B, and C intervals. Cumulative production from a horizontal borehole in this well (to January, 1, 2016) = 370,515 barrels of oil, 0.21 BCFG, and 6172 barrels of water (Utah Division of Oil, Gas and Mining, 2016). See figure 2 for location of Big Flat field.*

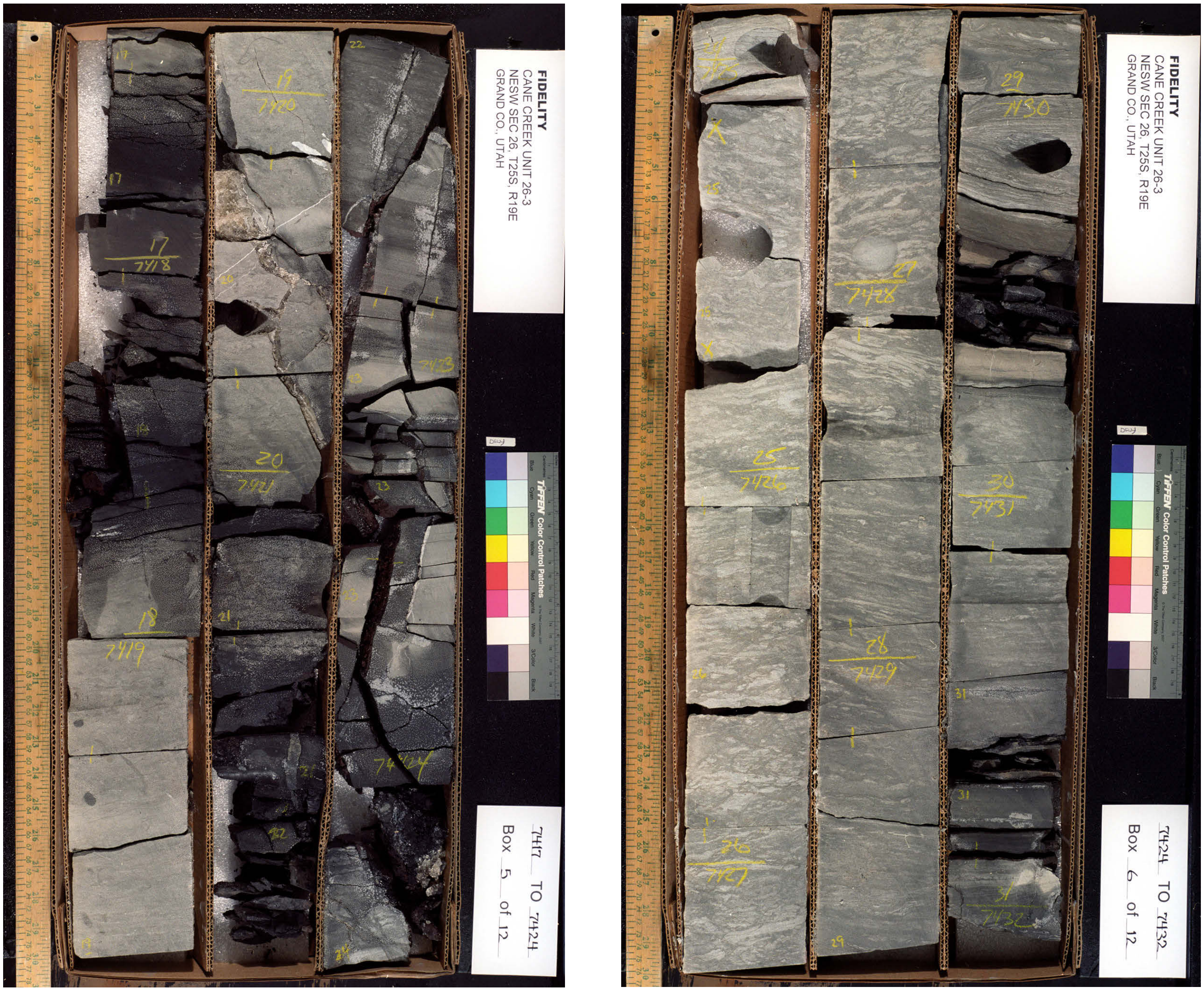

***Figure 15.** Typical fractured, silty to muddy dolomite (finely crystalline) with thin siltstone and black organic-rich shale beds of the B interval in the Cane Creek shale; Cane Creek Unit No. 26-3 well (well #10 on figure 10; section 26, T. 25 S., R. 19 E., SLBL&M), Big Flat field, San Juan County, Utah, slabbed core from 7418 to 7432 feet. Core photography by Triple O Slabbing, Denver, Colorado, provided courtesy of Fidelity Exploration & Production Company.*

and production. Similar to the overlying A interval, interbedding of various lithologies and carbonate fabrics exists within some B interval cuttings.

C Interval

Cuttings and core chip samples from the C interval consist of (1) microcrystalline dolomite, (2) fine- to coarsely crystalline dolomite, (3) anhydritic dolomite, silty dolomite, argillaceous silty dolomite, and shaly dolomite (4) black organic-rich shale, silty shale, and dolomitic shale, (5) dolomitic limestone, and (6) siltstone and argillaceous siltstone. Black, finely crystalline dolomite cuttings are likely organic rich. These lithologies can include patches of argillaceous dolomite or clusters of anhydrite in the matrix; well-preserved coarse rhombic dolomite crystals are also present in a few cuttings. Carbonate fabrics, most which are also dolomitized, range from grainstones to mudstones (the most common). Bryozoans (possibly colonial) are recognized in fossiliferous grainstones, packstone, and wackestones. Carbonate textural components include peloids in dolomitized grainstones to wackestones, oncolites, pisolites, and coated grains (figures 12D, 16C, 16D, and 16F). Possible microbialites are represented by dolomitized microlaminations (figure 16E), and lumpy or tubular structures.

MAPPING OF CANE CREEK EPIFLUORESCENCE

Four sets of maps were created for the entire Cane Creek shale, and the A, B, and C intervals based on EF readings: (1) the highest EF, (2) the average of the highest EF, (3) the high-

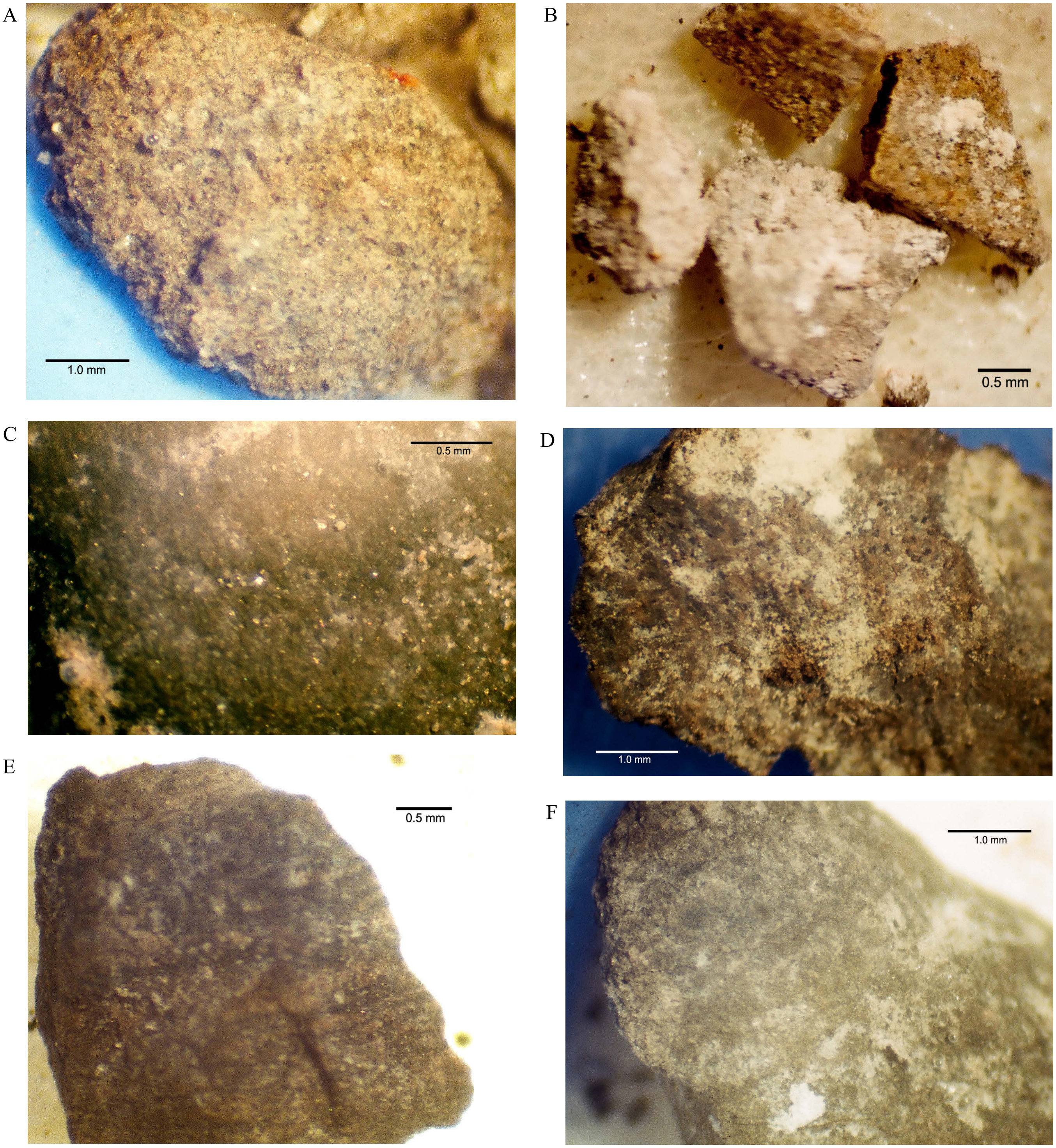

Figure 16. Principal rock types for epifluorescence work in Cane Creek shale cuttings observed with a binocular microscope. ***A.*** *Dolomitic sandstone cutting composed of quartz grains surrounded by dolomitic mud and/or cement from the 7380–90 foot sample in the Mineral Canyon No. 1-14 well (well #12; SW1/4SE1/4 section 14, T. 26 S., R. 19 E., SLBL&M, Grand County).* ***B.*** *Microcrystalline dolomite mudstone cutting displaying microporosity from the 6290–6300 foot sample in the Horsehead Unit No. 1 well (well #21; NW1/4SW1/4 section 18, T. 29 S., R. 21 E., SLBL&M, San Juan County).* ***C.*** *Dolomitized peloidal grainstone with minor amounts of quartz sand grains from the 6350–60 foot sample in the Horsehead Unit No. 1 well (well #21; NW1/4SW1/4 section 18, T. 29 S., R. 21 E., SLBL&M, San Juan County).* ***D.*** *Dolomitized peloidal/coated grain grainstone/packstone displaying good visible porosity from the 6360–70 foot sample in the Horsehead Unit No. 1 well (well #21; NW1/4SW1/4 section 18, T. 29 S., R. 21 E., SLBL&M, San Juan County).* ***E.*** *Dolomitized microbial laminite ("stromatolitic bindstone") displaying alternating light and dark crinkly laminations from the 5940–50 foot sample in the West Bridger Jack Unit No. 3 well (well #15; SE1/4SW1/4 section 3, T. 27 S., R. 21 E., SLBL&M, San Juan County).* ***F.*** *Dolomitized oncolitic/pisolitic rudstone from the 5960–70 foot sample in the West Bridger Jack Unit No. 3 well (well #15; SE1/4SW1/4 section 3, T. 27 S., R. 21 E., SLBL&M, San Juan County). See figure 10 for well number locations.*

est average EF, and (4) the average of the EF sample averages (appendix A). The intent of these maps was to use various EF data and combinations of EF averages to identify potential hydrocarbon "sweet spots." As shown on the maps and described in the following sections, some maps indicate the same fairways of hydrocarbon potential whereas other maps suggest possible areas to explore not identified on the others.

The highest EF maps show the highest EF value determined from all cuttings samples in each well from the entire Cane Creek and within each interval. The values for average of the highest EF maps were determined by averaging the highest EF from each cuttings sample interval in each well for the entire Cane Creek and the A, B, and C intervals. The values for the highest average EF maps represent the highest average EF out of all cuttings sample intervals in each well within the entire Cane Creek and the A, B, and C. Finally, the values for the average of the EF sample averages maps were determined by averaging the average of each cuttings sample interval in each well for the entire Cane Creek and the A, B, and C intervals.

Entire Cane Creek Shale

The map of the highest EF based on visual rating of well cuttings and core chips for the entire Cane Creek shale in each well (combining the results of the A, B, and C intervals) is shown on figure 17. In this map, and those that follow, mapped ratings that are considered highly prospective for oil are shown in dark purple (rating of 2.0–2.5) and green (rating higher than 2.5). A pronounced curvilinear fairway of very high (in green) ratings trends from northwest to southeast through the Paradox fold and fault belt. Note the lobes of high ratings that occur both northwest and southeast of the largest Cane Creek field—Big Flat (figures 2 and 10). The regions within these oil prospective lobes are sparsely explored. Areas to the northeast and southwest of the fairway defined in the map are characterized by relatively low EF ratings (in orange), and thus have lower potential for finding new oil reserves.

Figure 18 shows the average highest EF in each well based on visual rating for the entire Cane Creek shale. The same curvilinear fairway seen on figure 17 is shown with the average highest rating (in purple) trending from northwest to southeast. A large, elongate lobe present in Big Flat field continues to the northwest in light green (rating of 2.0–2.5). This lobe represents a relatively large, untested area of the Cane Creek play. It includes the small Hell Roaring field (figures 2 and 10) that has the same average highest EF rating (2.8) as a well in Big Flat field (well #10). A small north-northeast to south-southwest-trending ovate lobe, also with an average highest EF rating of 2.5 or higher just southeast of Big Flat, corresponds to a similar lobe at the same locale as observed on figure 17. A boot-shaped area, which includes Hatch Point field (figures 2 and 10), and a very small lobe at the end of the fairway have average highest EF ratings of 2.0 (in dark purple), and thus may also represent additional exploration potential providing there is adequate porosity and permeability.

Figure 19 shows the highest average EF in each well based on visual rating for the entire Cane Creek shale. Again, a pronounced curvilinear fairway of anomalous fluorescence ratings exists that follows the same northwest to southeast trend seen in the highest EF map (figure 17). The anomalous trend displays lower average ratings (displayed in both green and purple) than highest EF ratings shown on figure 17. The lobes of highest average ratings that occur both northwest and southeast of the Big Flat field are not as pronounced nor are they as large and continuous as those suggested by the highest EF map (figure 17). Some of the smaller fields containing productive Cane Creek wells display highest average ratings that are less than the area around and possibly to the northwest of Big Flat field.

Figure 20 shows the average of the EF sample averages in each well based on visual rating of the Cane Creek shale. The curvilinear pattern remains with three distinct lobes of high EF ratings. Once again, the area of greatest potential is the large lobe with an EF rating of 2.0 (in dark purple) northeast of Big Flat field.

A Interval

The map of the highest EF in each well based on visual rating of the A interval, the uppermost stratigraphic portion of the Cane Creek shale, is shown on figure 21. A constricted fairway of very highest (in green) ratings for the A interval follows the same general trend as the total Cane Creek thickness highest ratings. Very prospective A interval sections appear to exist in large lobes to the northwest and southeast of Big Flat field. The northern and western portions of Big Flat field seem to have lower highest ratings than the southeastern and eastern productive areas. High-risk areas that have low ratings (in orange) within the A interval occur at the northwest end of the highest fairway as well as to the northeast and southwest of the overall favorable ratings fairway.

Figure 22 shows the average highest EF in each well based on visual rating of the A interval. The overall curvilinear Cane Creek fairway is shown where two distinct, narrow lobes have an average highest EF of 3.0 (in dark green) northwest and southeast of Big Flat field that lies in a saddle in between. A dry hole, the Cane Creek State No. 1-16 (section 36, T. 27 S., R. 20 E., SLBL&M, Grand County, well #16, figure 10 and table 3) has high ER ratings (3.0 and 3.1) in the A interval, creating the small lobe shown on figure 21 and the thickness maps by Morgan and others (2014) and Carney and others (2014). Thus, the B interval in this well and the immediate surrounding area, deserves closer examination for oil potential. A larger, somewhat round lobe is mapped towards the southeast end of the fairway and has an EF rating of 2.5 (in light green). This area includes Hatch Point field along the northwestern edge of the lobe and a large, sparsely drilled area of the Cane Creek shale play to the southeast.

Figure 23 shows the highest average EF in each well based on visual rating of the A interval. The anomalous trend on this

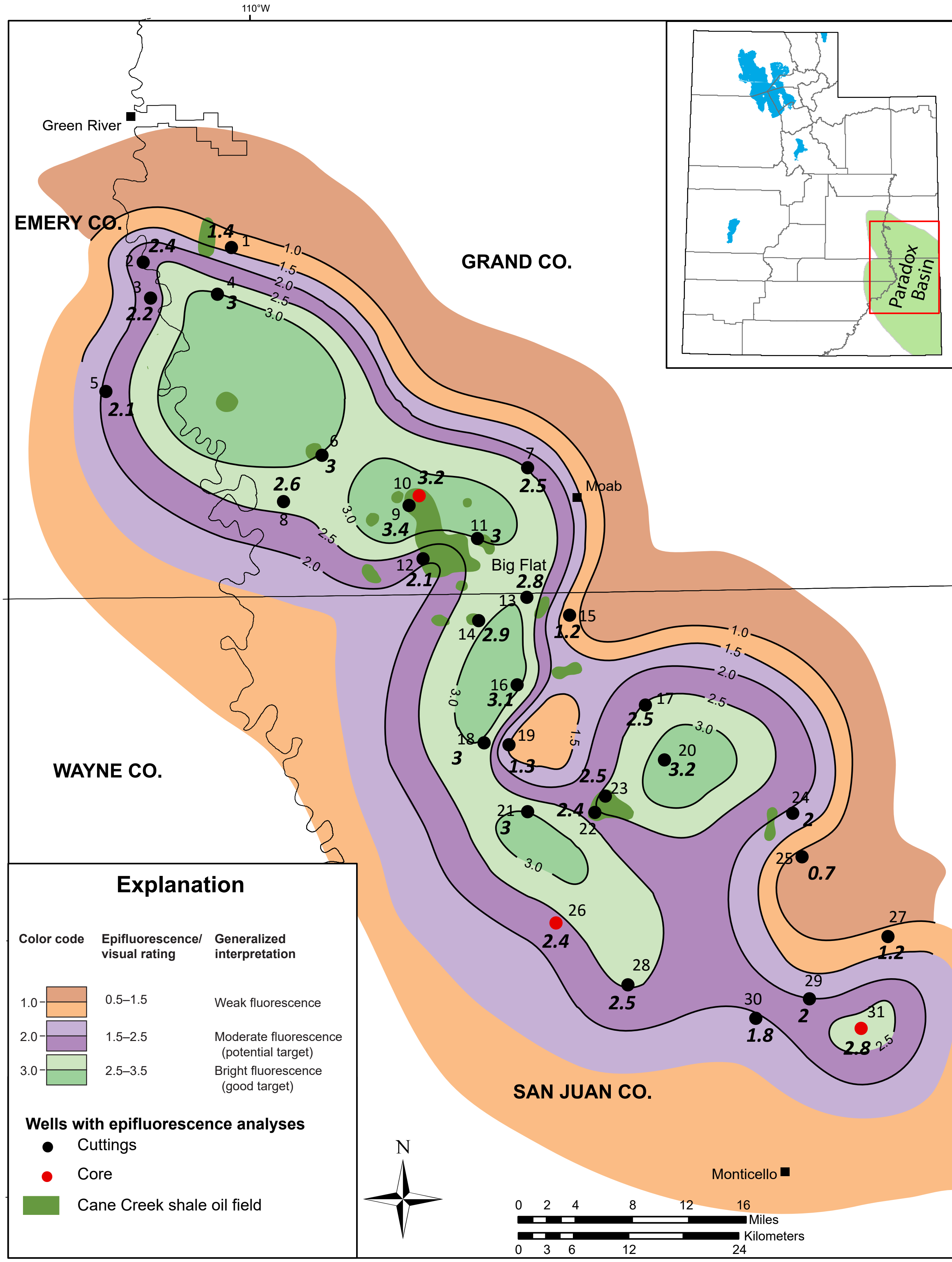

Figure 17. The highest epifluorescence based on visual rating of Cane Creek well cuttings and core chips. See table 3 for list of wells corresponding to the numbers by the black or red dots.

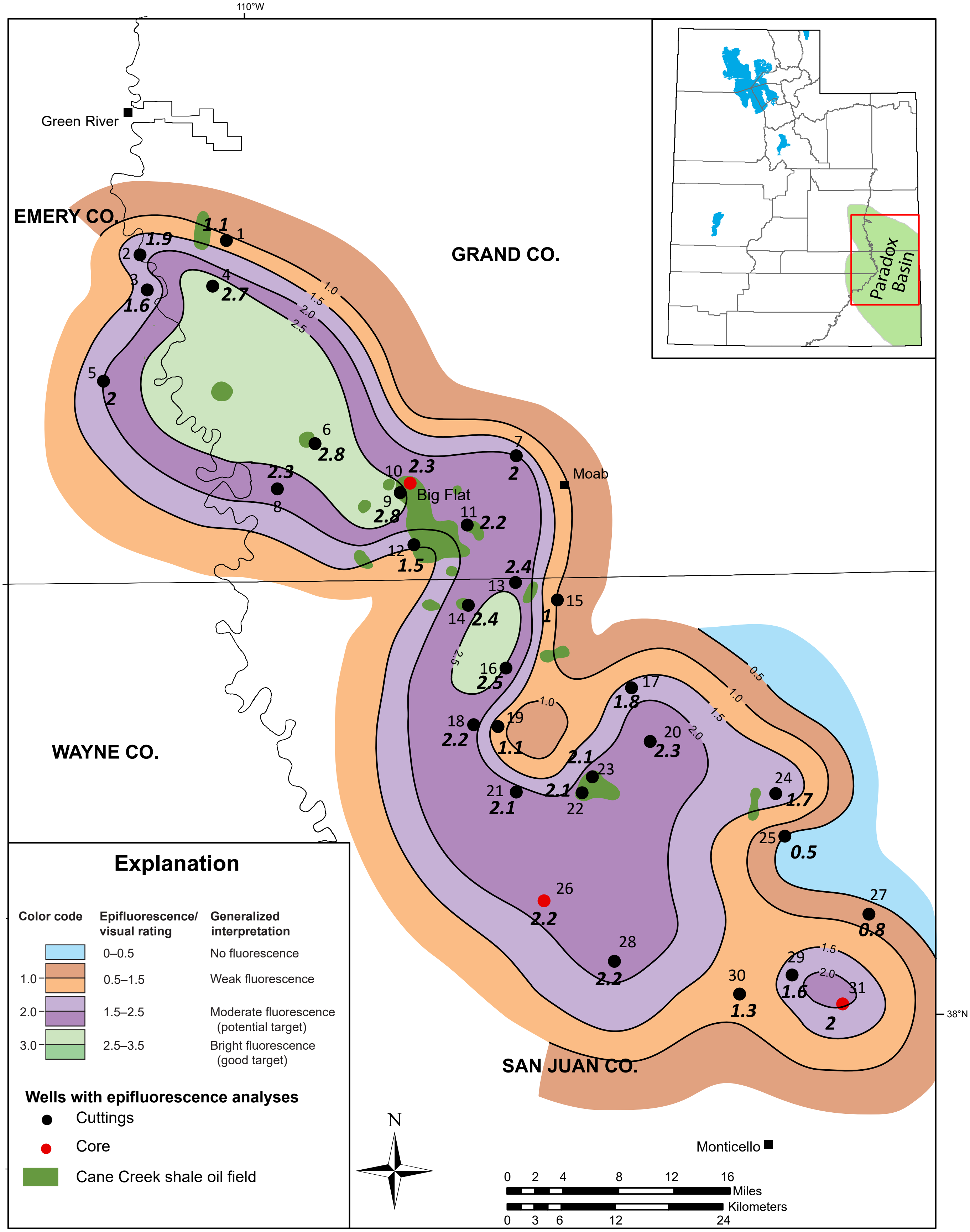

Figure 18. The average highest epifluorescence based on visual rating of Cane Creek well cuttings and core chips. See table 3 for list of wells corresponding to the numbers by the black or red dots.

Figure 19. *The highest average epifluorescence based on visual rating of Cane Creek well cuttings and core chips. See table 3 for list of wells corresponding to the numbers by the black or red dots.*

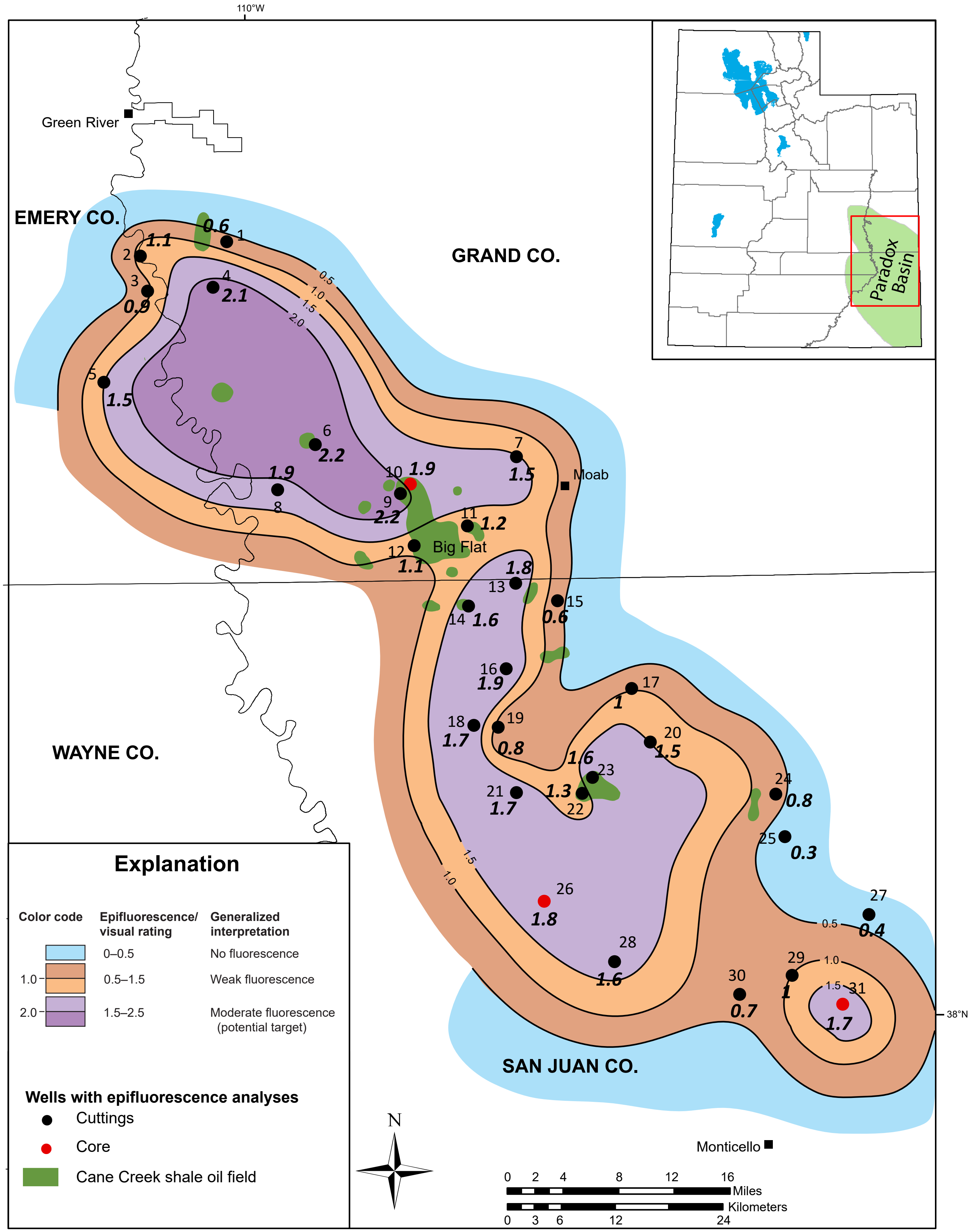

__Figure 20.__ The average of the epifluorescence sample averages based on visual rating of Cane Creek well cuttings and core chips. See table 3 for list of wells corresponding to the numbers by the black or red dots.

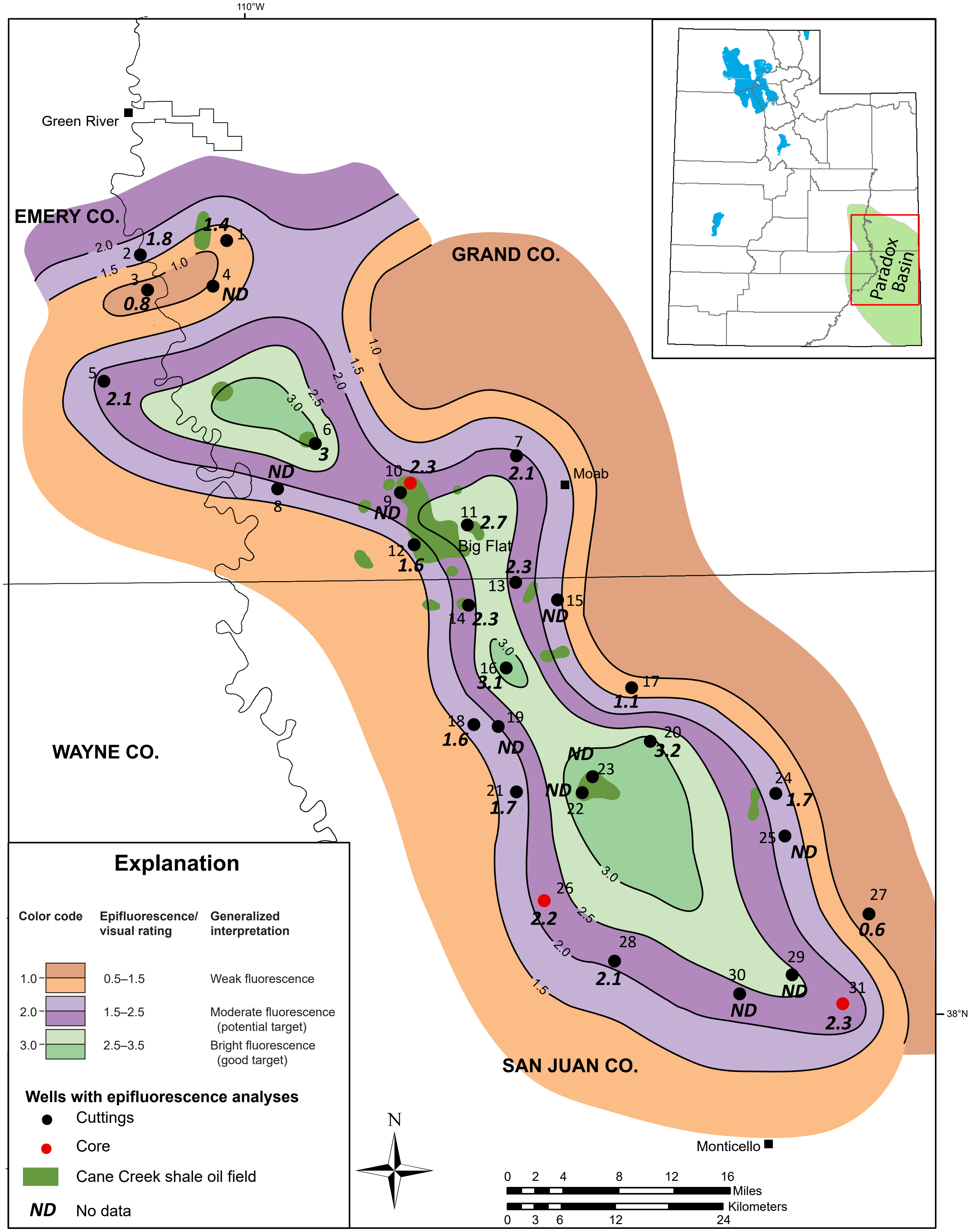

Figure 21. The highest epifluorescence based on visual rating of Cane Creek well cuttings and core chips, A interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.

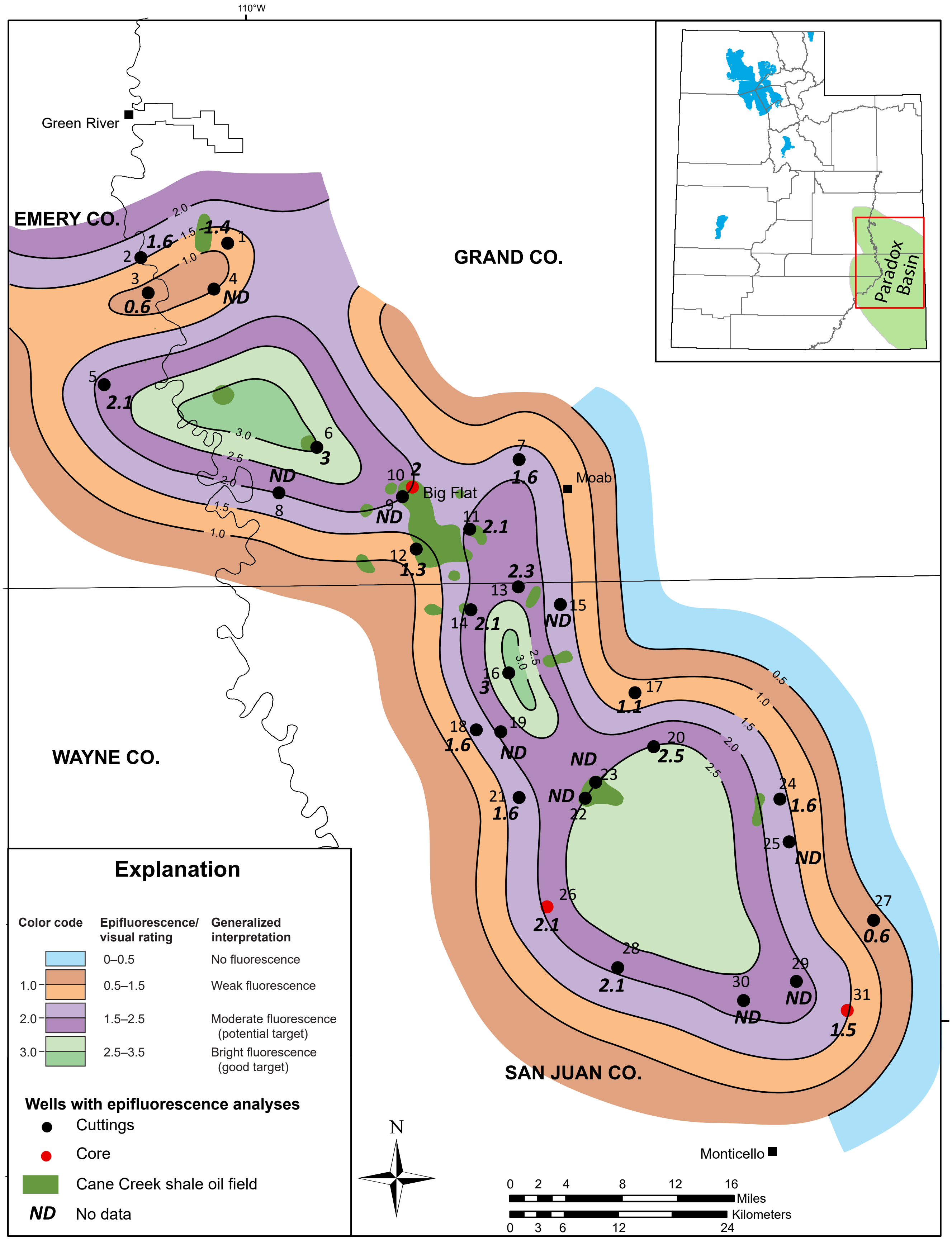

Figure 22. *The average highest epifluorescence based on visual rating of Cane Creek well cuttings and core chips, A interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.*

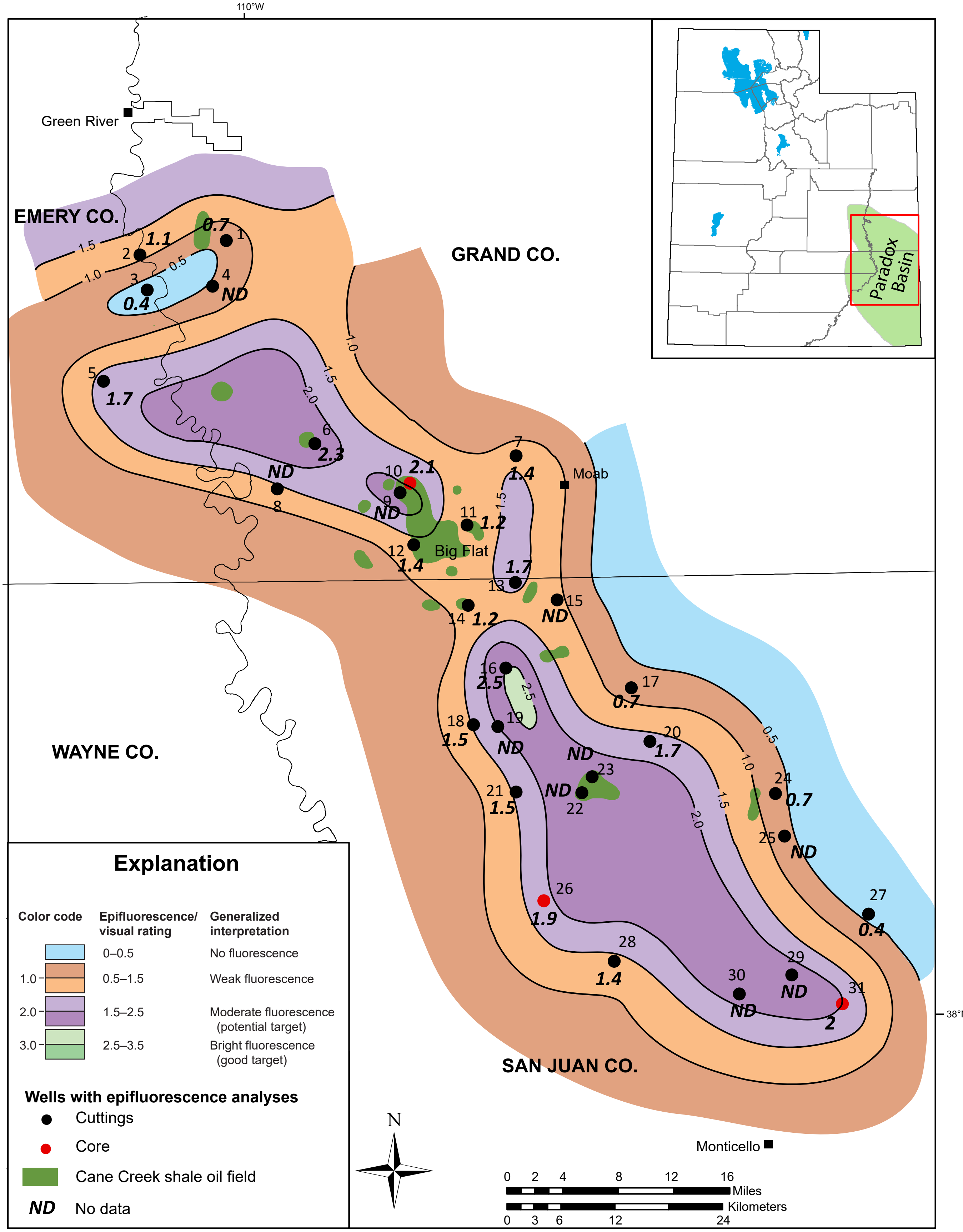

Figure 23. *The highest average epifluorescence based on visual rating of Cane Creek well cuttings and core chips, A interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.*

map displays lower average ratings (shown in both green and dark purple) than highest EF ratings for the A interval shown on figure 21. Fragmented or isolated pods of highest average ratings (shown in green and dark purple) suggest that the A interval does not have uniform prospectivity or productivity along the favorable Cane Creek shale fairway. The southern portions of Big Flat field do not rate very well for the A interval using the highest average ratings, suggesting that the A interval may not be highly productive through the entire area of the field. Very prospective A interval sections appear to exist in discrete lobes to the northwest and southeast of Big Flat field as determined by the high average ratings (in green and dark purple). High-risk areas that have low ratings (in orange and blue) within the A interval occur at the northwest end of the highest average fairway as well as to the northeast and southwest of the overall favorable ratings fairway.

Figure 24 shows the average of the EF sample averages in each well based on visual rating of the A interval. The overall Cane Creek shale fairway appears very similar to that shown on figure 23, but narrower. However, only the west-northwest- to east-southeast-trending lobe just west of Big Flat field has an EF rating high enough (2.0) to suggest the potential for moderate oil productivity in the A interval. Another very small lobe of the same EF rating is associated with the Cane Creek State No. 1-36 well (well #16).

B Interval

The map of the highest EF in each well based on visual rating of the B interval, the primary reservoir and the middle stratigraphic portion of the Cane Creek shale zone, is shown on figure 25. A well-defined fairway of very highest (in green and dark purple) ratings for the B interval follows the same general trend as the total Cane Creek shale thickness highest ratings. All of the Cane Creek oil fields to date have the B interval highest ratings that are rated very high (in green and purple). Based on EF ratings, the B interval appears to be the best and most widespread Cane Creek shale interval for oil production and prospectivity. Very prospective B interval sections appear to exist in lobes to the northwest and southeast of Big Flat field. High-risk areas that have low ratings (in orange) within the B interval occur only to the northeast and southwest of the overall favorable ratings fairway.

Figure 26 shows the average highest epifluorescence in each well based on visual rating of the B interval. It shows the same well-defined curvilinear Cane Creek fairway that is mapped for highest EF on figure 25. However, there are fewer lobes of high EF and surprisingly a significant part of Big Flat field lies in the relatively low 1.5–2.0 EF rating range (in light purple). A pear-shaped, west-northwest- to east-southeast-trending lobe, including the northern part of Big Flat field and Hell Roaring field, has an EF rating 2.5 (in light green) indicating movable oil potential in the B interval. The southern part of the fairway shows a large area with a rating 2.0 and higher—a good indication of potential and now confirmed with the recent discovery of Cane Creek production in the La Sal No. 29-28 well (section 29, T. 29 S., R. 23 E., SLBL&M, San Juan County; see figure 2 and table 2). This area lies in between Hatch Point and Wilson Canyon fields, each with lower EF ratings in the B interval (1.5–2.0).

Figure 27 shows the highest average EF in each well based on visual rating of the B interval. The anomalous trend displays lower average ratings (shown in both green and purple) than highest EF ratings for the B interval shown on figure 25. Discontinuous or patchy areas of highest average ratings (shown in green and dark purple) suggest that the B interval may not have uniform prospectivity or productivity along the favorable Cane Creek shale fairway. Relatively large undrilled areas exist in which the B interval appears to be prospective for oil accumulations.

Figure 28 shows the average of the EF sample averages in each well based on visual rating of the B interval. The Cane Creek fairway appears very similar to that shown on figure 25 displaying multiple lobes of higher EF ratings. Again the pear-shaped, west-northwest- to east-southeast-trending lobe is present, including the northern part of Big Flat field and Hell Roaring field. It has an EF rating 2.0–2.5 suggesting oil is present in the B interval and may be capable of production where there is good porosity and permeability. Smaller lobes to the south and southeast of Big Flat have EF ratings of 2.0.

C Interval

The map of the highest EF in each well based on visual rating of the C interval, the lowest stratigraphic portion of the Cane Creek shale zone, is shown on figure 29. A well-defined fairway of very highest ratings (in green and dark purple) for the C interval is smaller in area than the fairways defined on the other rating maps. The most prospective areas for the C interval may occur in a continuous, curvilinear fairway to the northwest, south, and southeast of Big Flat field. Some of the wells are labeled “ND” (No Data) because the C interval is either absent or very thin in those wells. High-risk areas that have low ratings (in orange) within the C interval occur only to the northeast and southwest of the overall favorable ratings fairway.

Figure 30 shows the average highest EF in each well based on visual rating of the C interval. As expected the EF ratings show relatively low potential in the Cane Creek fairway including Big Flat field. There is a large west-northwest- to east-southeast-trending lobe that curves around Big Flat field and extends to the west with EF ratings of 2.5 (in light green). This lobe includes Long Canyon field (figures 2 and 10 [well #11]); however, caution must be applied to this interpretation as the data are limited. An additional small, north- to south-trending lobe is shown on the center of the Cane Creek fairway whereas the remaining areas show very limited potential with EF ratings less than 2.5.

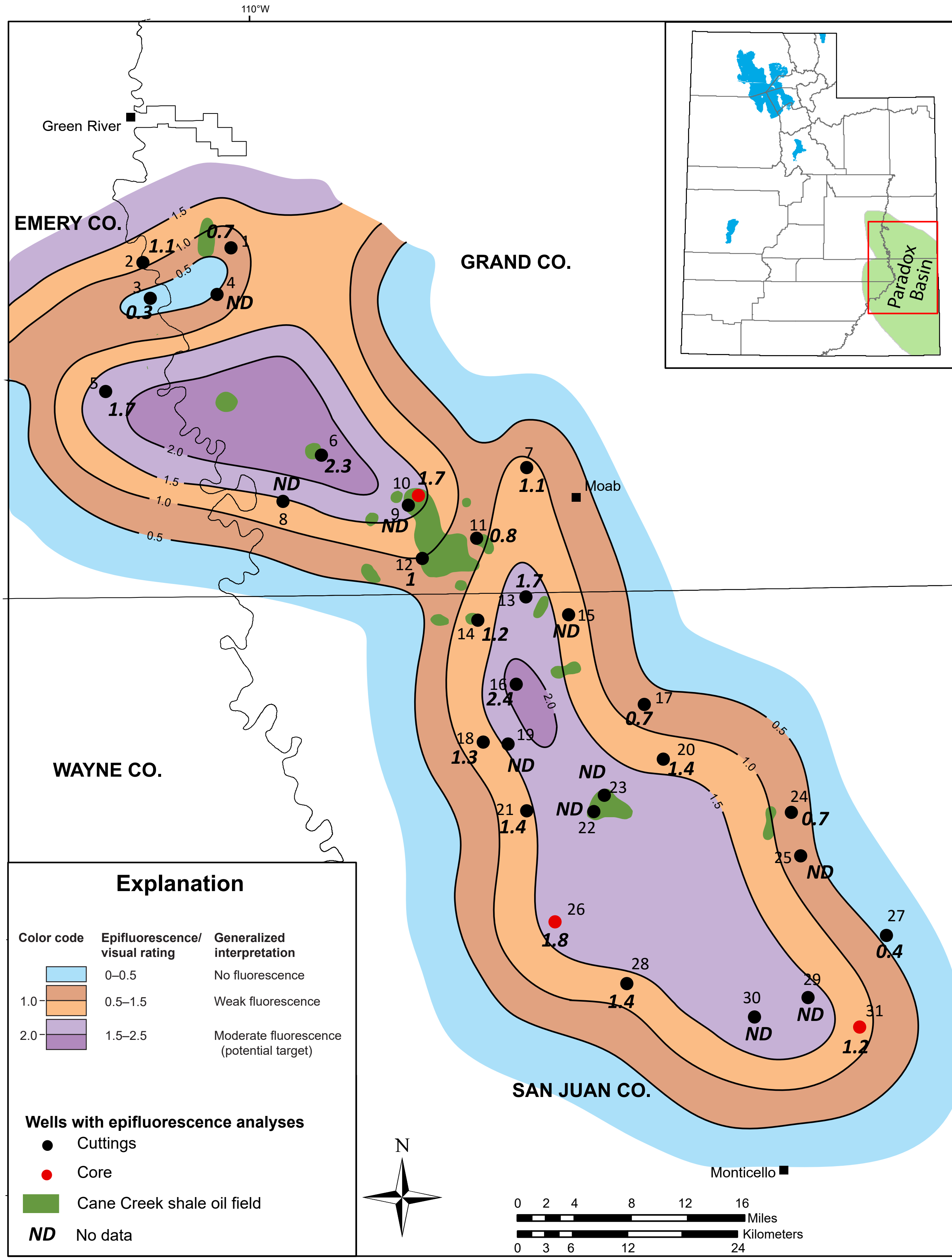

Figure 24. The average of the epifluorescence sample averages based on visual rating of Cane Creek well cuttings and core chips, A interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.

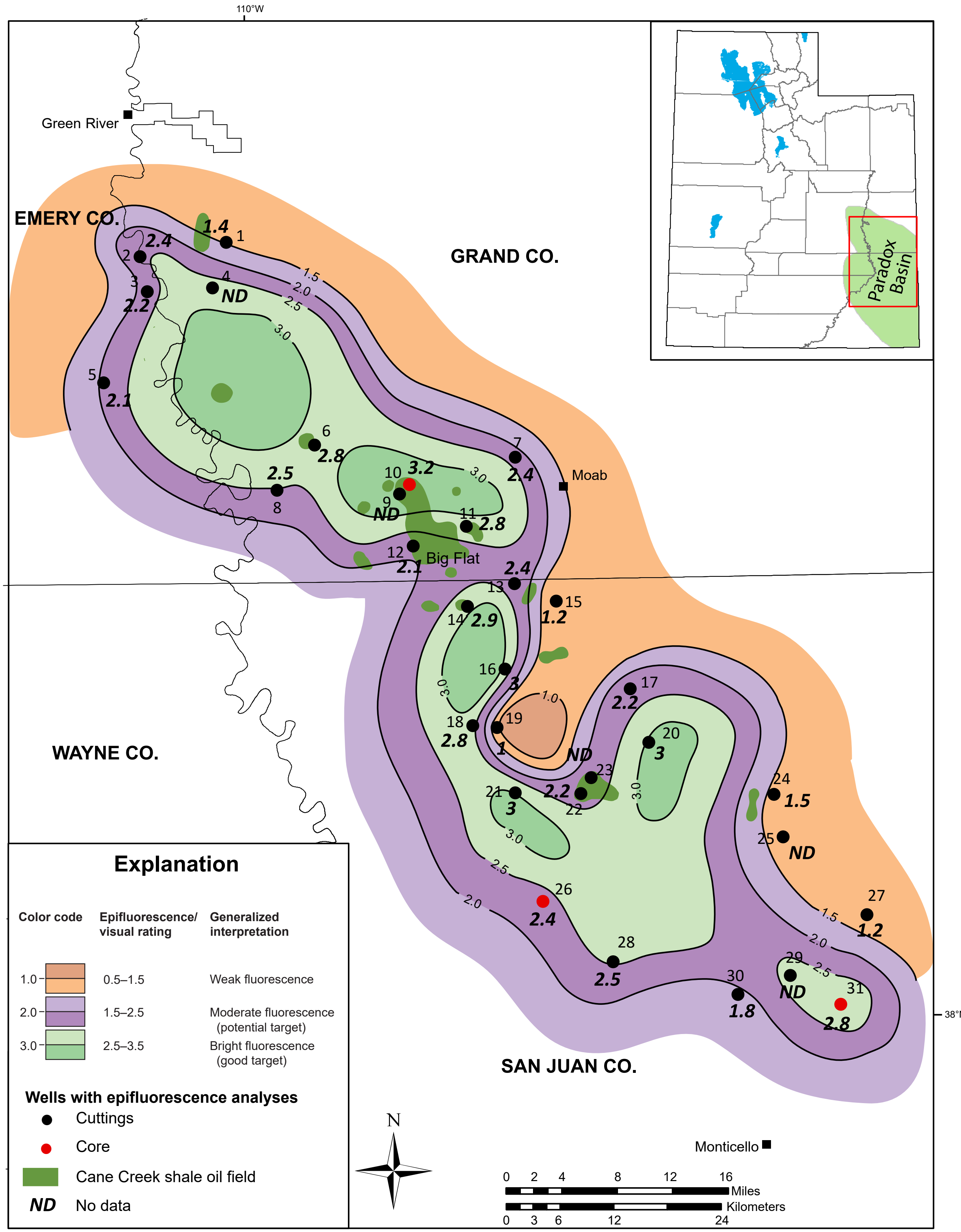

Figure 25. *The highest epifluorescence based on visual rating of Cane Creek well cuttings and core chips, B interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.*

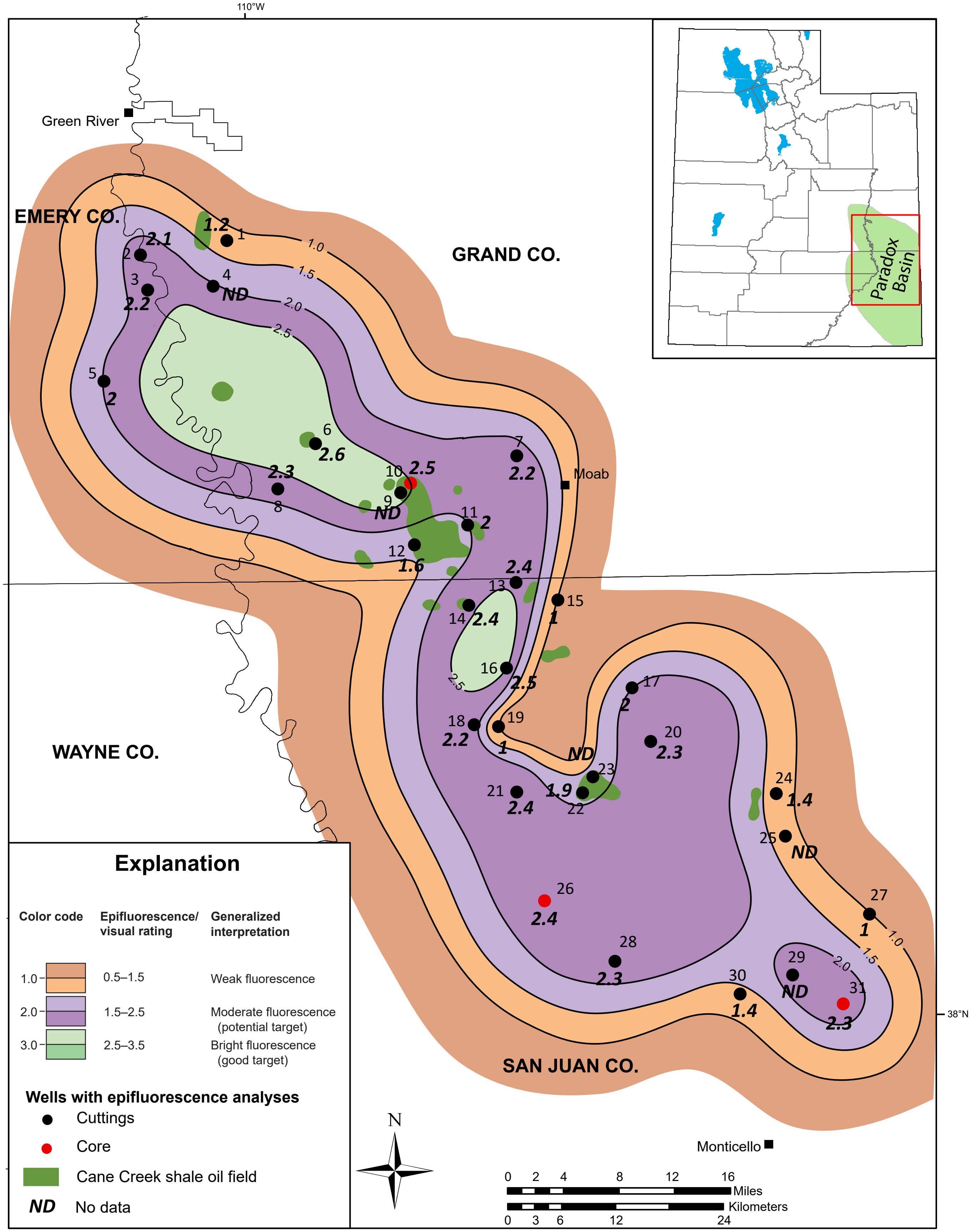

Figure 26. The average highest epifluorescence based on visual rating of Cane Creek well cuttings and core chips, B interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.

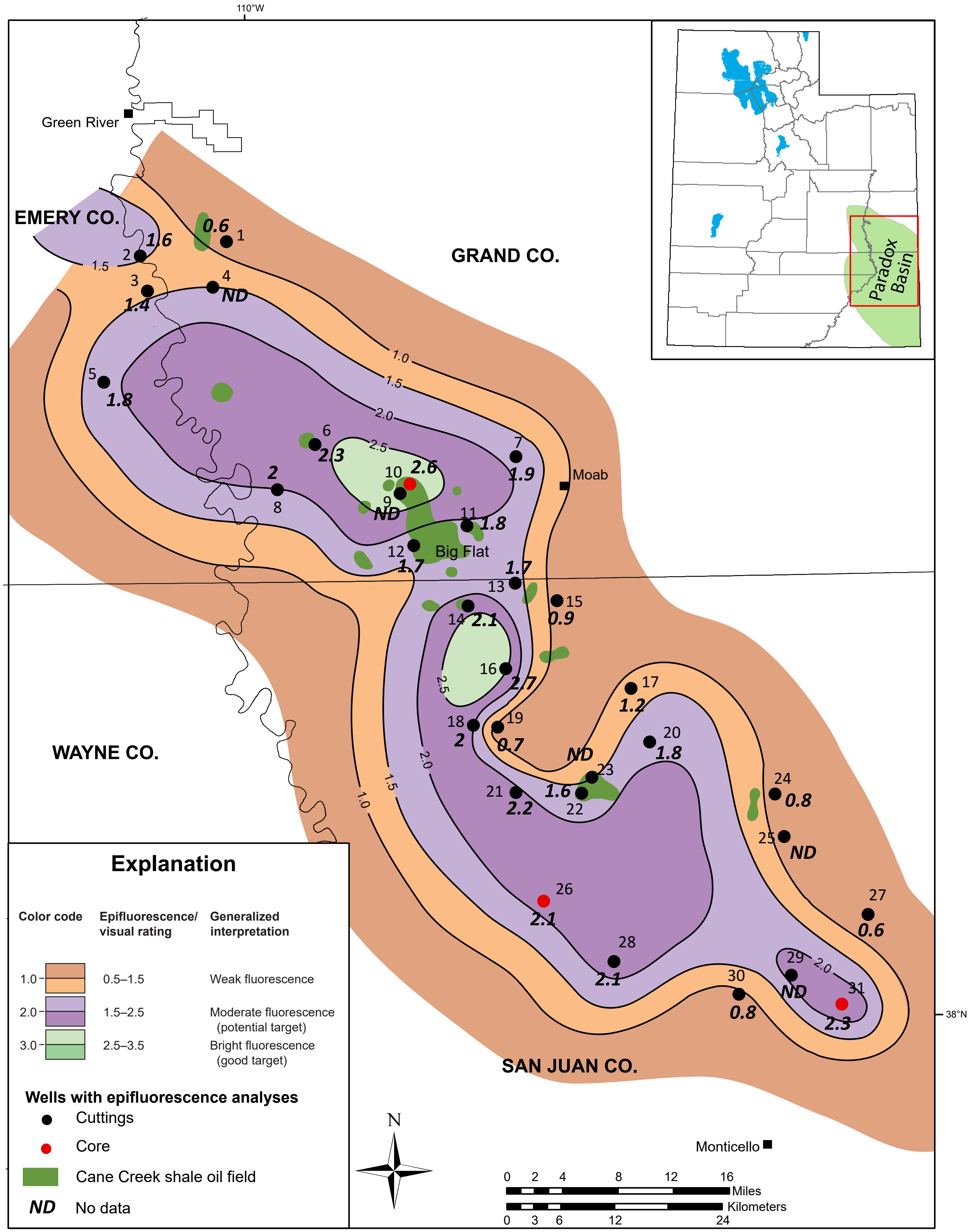

Figure 27. *The highest average epifluorescence based on visual rating of Cane Creek well cuttings and core chips, B interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.*

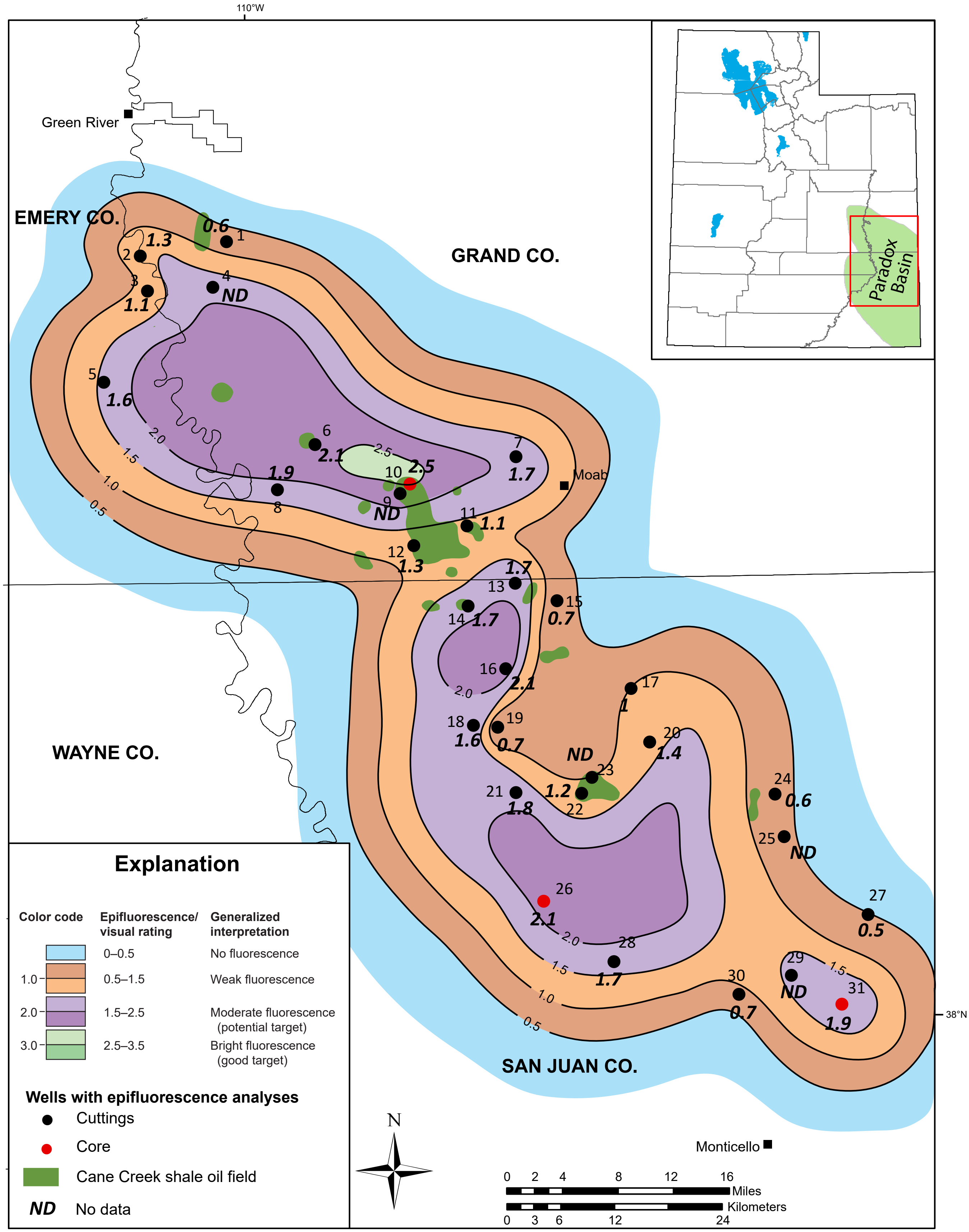

Figure 28. The average of the epifluorescence sample averages based on visual rating of Cane Creek well cuttings and core chips, B interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.

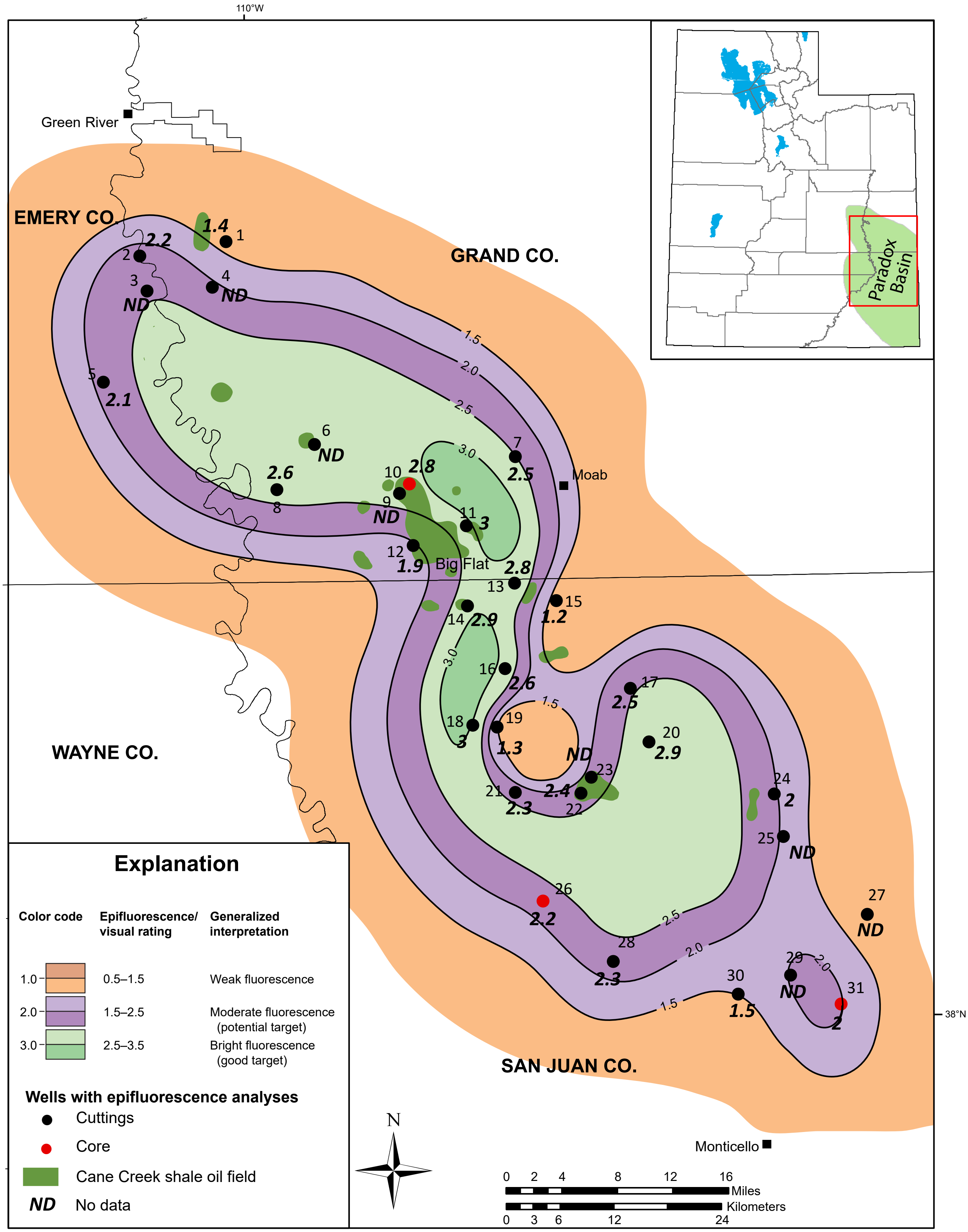

Figure 29. *The highest epifluorescence based on visual rating of Cane Creek well cuttings and core chips, C interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.*

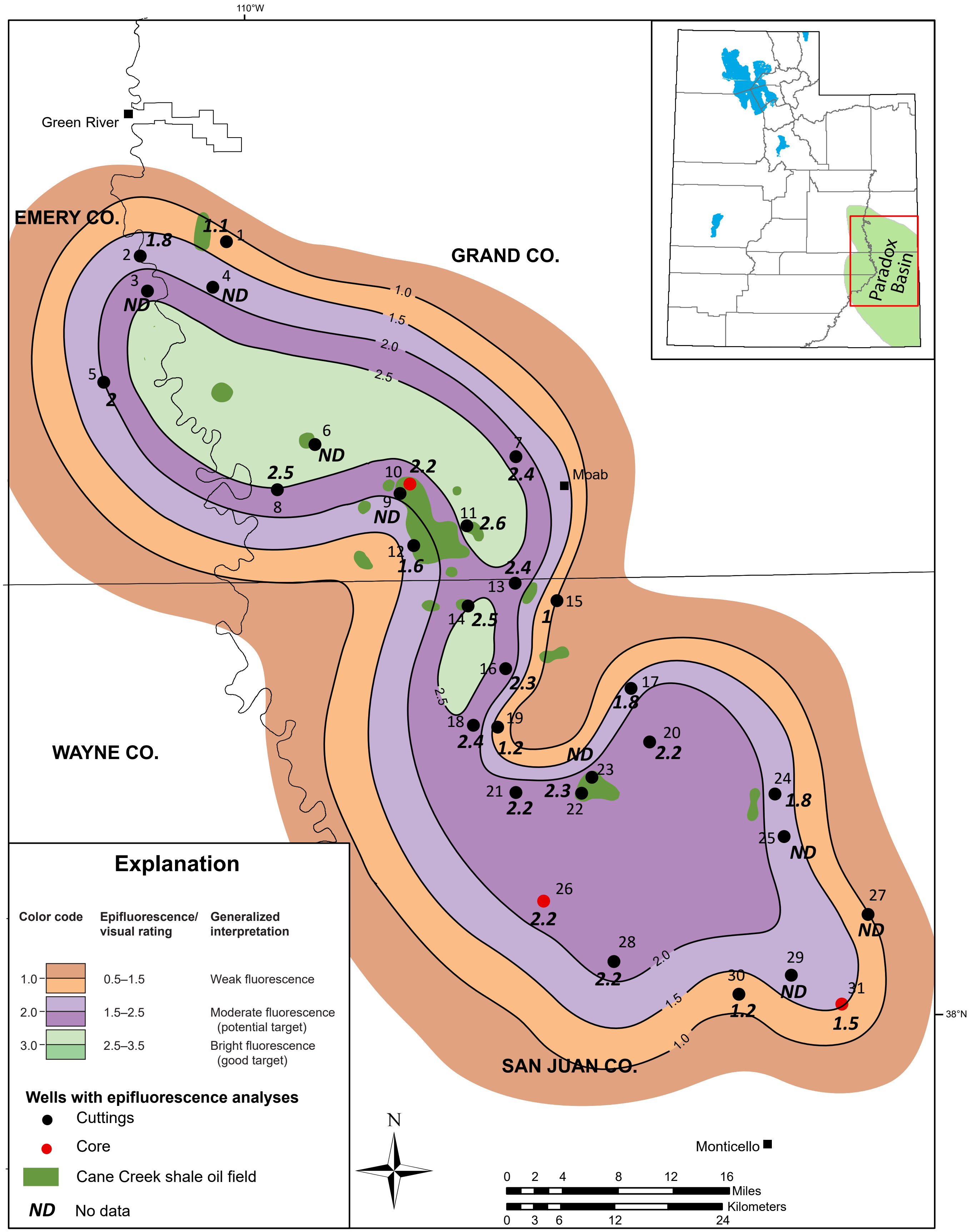

Figure 30. The average highest epifluorescence based on visual rating of Cane Creek well cuttings and core chips, C interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.

Figure 31 shows the highest average EF in each well based on visual rating of Cane Creek well cuttings and core chips, C interval. The anomalous trend displays lower average ratings (shown only in purple) than highest EF ratings for the C interval shown on figure 29. A favorable Cane Creek shale fairway for the C interval based on highest average ratings is somewhat narrowed and smaller than the fairway defined on the previous map using highest EF ratings. Relatively large areas exist that may have high exploration risk associated with them (the orange map areas) for oil accumulations within the C interval based on highest average ratings.

Figure 32 shows the average of the EF sample averages in each well based on visual rating of the C interval. In this map the Cane Creek fairway is very narrow, showing limited potential; most of it has EF ratings of less than 2.0. A relatively large, west-northwest- to east-trending lobe is mapped in the northern part of the fairway. However, this lobe is based on only two data points. Therefore, the map of the average of the EF sample averages confirms that the C interval is the lower seal (and a probable source) for the oil in the overlying B interval and should not be a drilling target.

STATISTICAL ANALYSIS

The EF data collected were analyzed to determine basic statistical values—the arithmetic mean (or average), mode, median, and standard deviation. About 2650 EF rating measurements from well cuttings and core chips were compiled from 256 samples from 31 wells (see section on Methods, and figure 10, table 3, and appendix B). Each sample covers 10 feet of Cane Creek section (with a few exceptions) and usually represents 10 measurements per sample, unless not enough good quality cuttings were available. For this statistical analysis, the average EF value recorded for each sample was averaged for the A, B, and C intervals rating (see appendix A and EF rating maps – figures 20, 24, 28, and 32). Histograms showing the distribution of these EF averages by Cane Creek interval are shown on figure 33. Note that not all three of these intervals were encountered in all 31 wells. As shown on figure 33, the A interval was sampled in 21 of the wells, the B interval in 26 wells, and the C interval in 23 wells, and thus no one dataset was significantly higher or lower than the others. Figure 33 also shows that the mean, median, and standard deviation (std.) of the average of the EF sample averages for these stratigraphic intervals are similar. However, the distributions do show some differences. These differences may be useful to evaluate the potential of the A and C intervals when compared to the productive B interval. The distributions may also assist interpretation of the various EF maps (figures 17 through 32).

The statistical mode is the EF average that appears most often in each dataset and represents the value most likely to be sampled. The EF distribution shown for interval A is dominated by a single peak, which includes the mean value of 1.25. Thus, the dataset is unimodal. The EF distribution for interval B is bimodal with EF peaks near 0.75 and 1.65 that bracket, but do not include the mean value of 1.41. The distribution for interval C is likewise bimodal with a broad peak near EF value 0.9, and another peak near EF value 1.65; neither of these peaks include the EF mean value of 1.39.

The median is the EF value that separates the higher half from the lower half or the middle EF value of each dataset. The medians for the EF sample averages from the A, B, and C intervals are 1.2, 1.5, and 1.5, respectively. In this case, the medians for the B and C intervals are the same, like the means for these same intervals. However, unlike the means, the medians are not skewed by large or small EF values. Such values can affect the means and thus the median may represent a more common value. For example, the B interval contains both high and low EF sample averages that lead to a mean of 1.41 whereas the median is 1.5 and therefore more typical. It is important to note that the means and medians for the three intervals are, in reality, quite close, indicating that the data have not been skewed to a large extent.

The standard deviation quantifies the amount of variation or spread of the EF sample average data. The standard deviations for the EF sample averages from the A, B, and C intervals are 0.56, 0.56, and 0.46, respectively. All three intervals show similar ranges of variation. For example, the A and B intervals have the same standard deviation (0.56). Perhaps surprisingly, the potentially multimodal C interval shows a slightly smaller range of variation (standard deviation = 0.46).

The statistical analysis of the datasets from the average of the epifluorescence sample averages for the A, B, and C intervals shows relatively minor differences between most of the basic statistical values generated from each dataset. Recall that only the B interval is currently productive in the Cane Creek shale. Thus, this analysis supports the additional and untested potential for the A and C intervals identified by the EF maps.

SUMMARY AND CONCLUSIONS

The Cane Creek shale play in the Pennsylvanian Paradox Formation, Paradox fold and fault belt of the Paradox Basin, southeastern Utah, contains potential oil-prone exploration areas identified from oil shows recognized using EF microscope techniques on cuttings, core chips, and uncovered thin sections. EF is a noninvasive and nondestructive procedure that can be done using a petrographic microscope equipped with reflected light capabilities, mercury-vapor light, and appropriate filtering. Sample preparation is relatively inexpensive. EF allows one to observe the presence or absence of oil shows, especially in the dolomites, limestones (including microbialites), siltstones, and sandstones of the Cane Creek. Samples displaying significant fluorescence help define areas where hydrocarbons may have migrated or accumulated. If no fluorescence

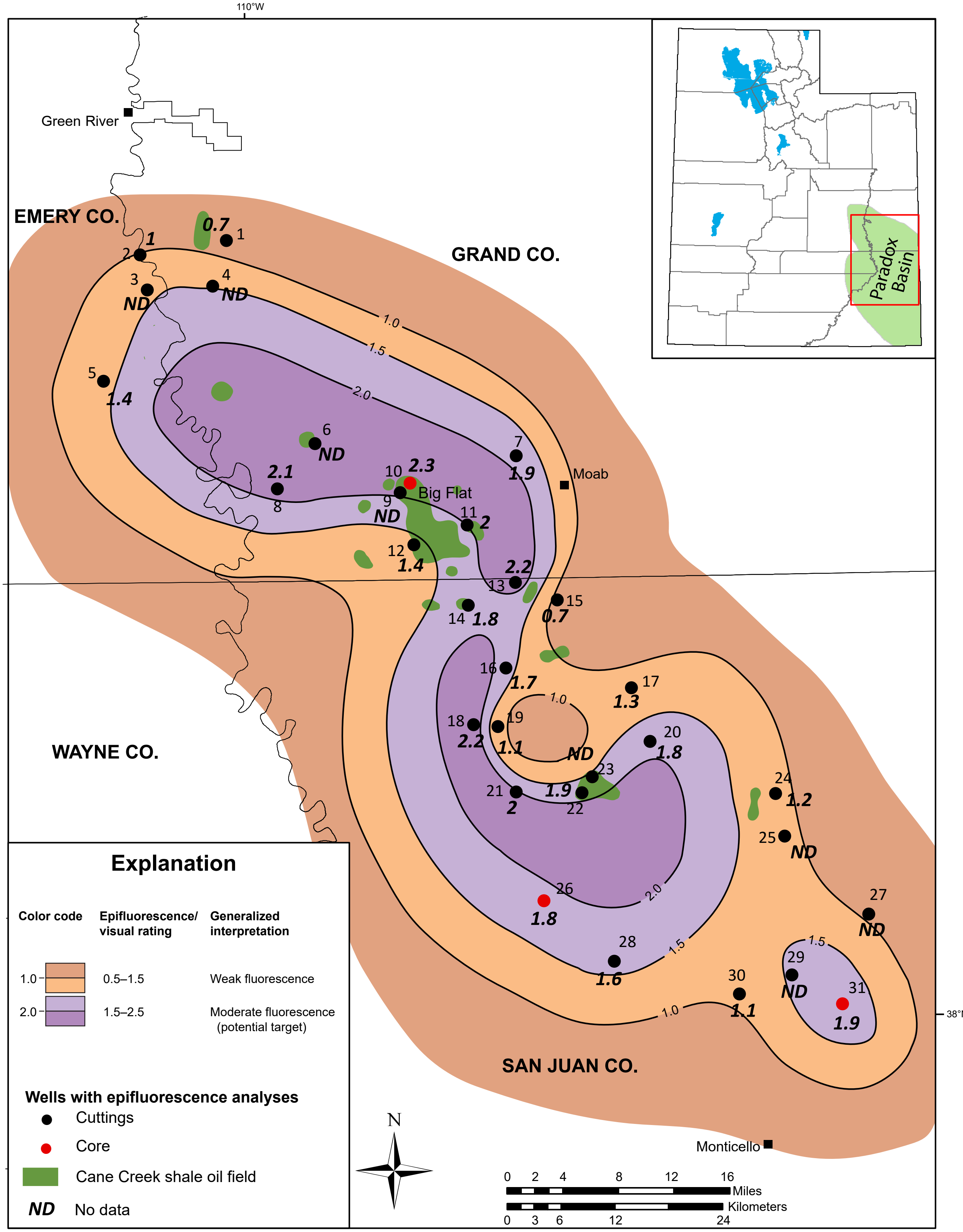

Figure 31. The highest average epifluorescence based on visual rating of Cane Creek well cuttings and core chips, C interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.

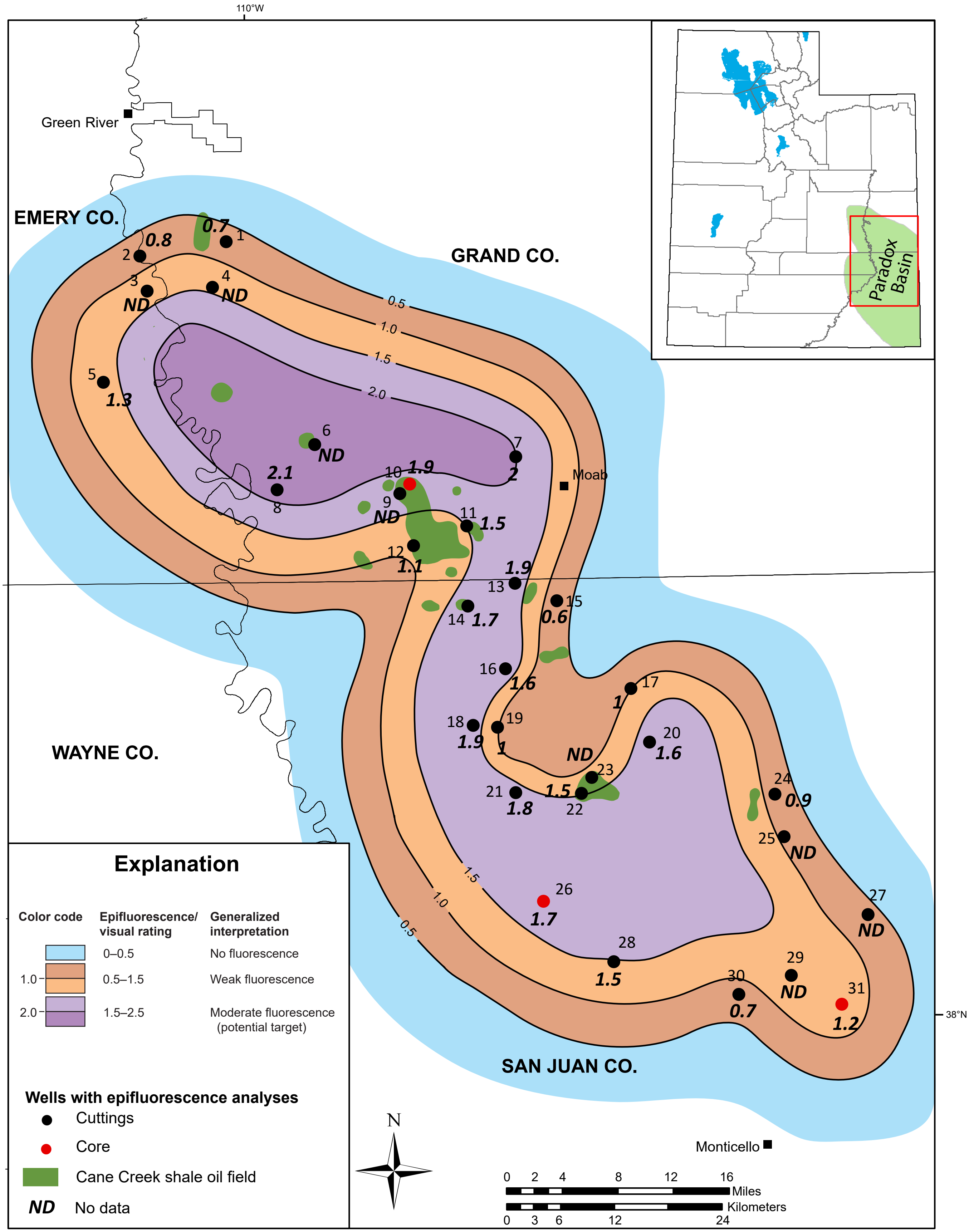

Figure 32. *The average of the epifluorescence sample averages based on visual rating of Cane Creek well cuttings and core chips, C interval. See table 3 for list of wells corresponding to the numbers by the black or red dots.*

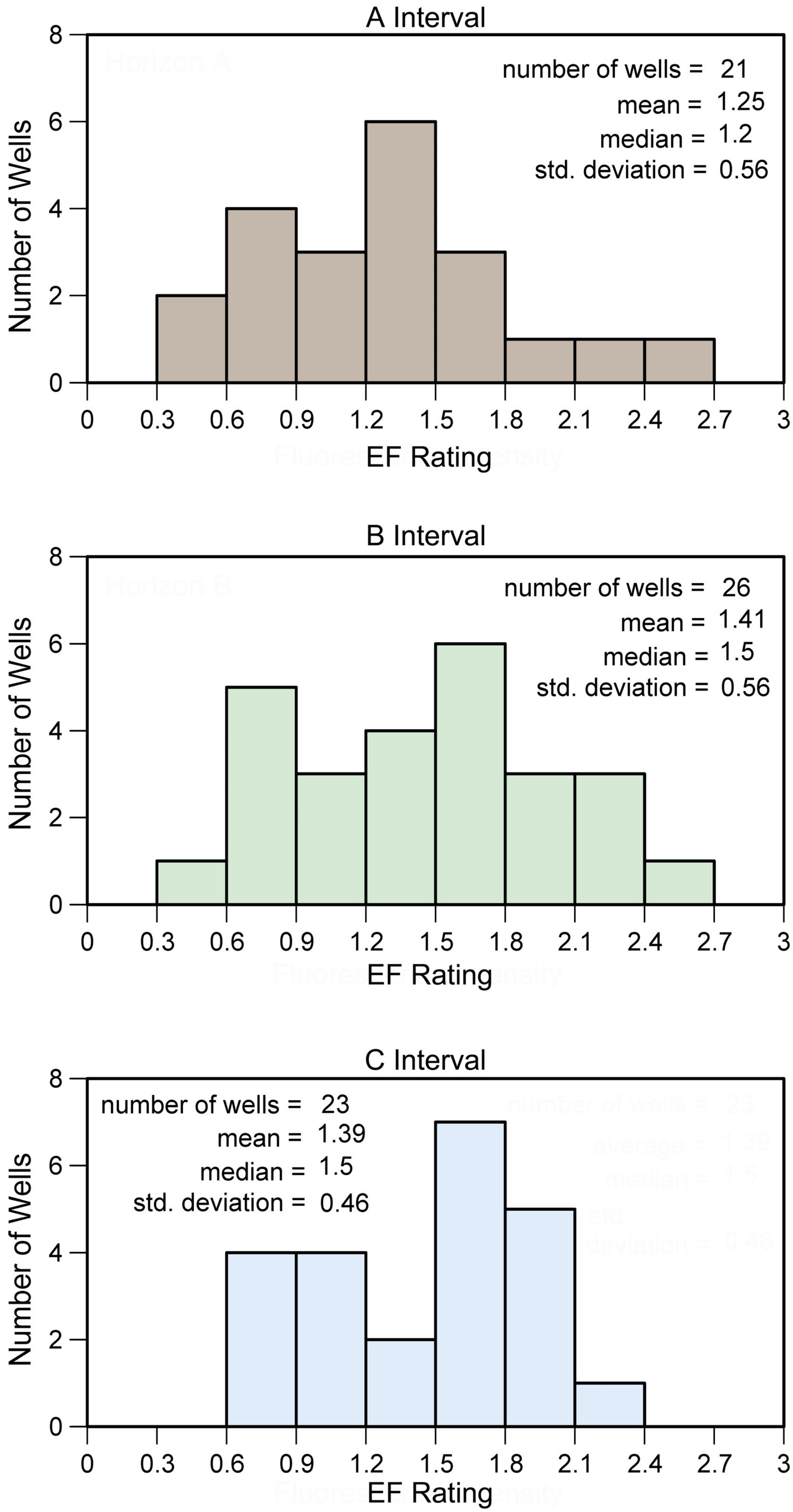

Figure 33. *Histograms for the A, B, and C intervals plotting the average of the epifluorescence sample averages versus number of wells. The statistical mean, median, and standard (std.) deviation from each dataset are also provided.*

is observed in porous dolomites for example, the samples are also good representatives of areas where liquid hydrocarbons are not currently stored/trapped in the subsurface.

Cuttings and core chips from 31 productive and dry exploratory wells penetrating the Cane Creek shale in the Utah portion of the Paradox fold and fault belt were examined under a binocular microscope. Over 2650 representative samples of porous dolomite, siltstone, sandstones, limestones, and some shales were selected from various intervals over the Cane Creek section for EF evaluation. A qualitative visual "rating" scale (a range and average) based on EF evaluation was applied to the group of handpicked cuttings (or core chips) from each depth in each well. The highest, average highest, highest average, and average of the averages of EF ratings from each well were plotted and mapped for the entire Cane Creek shale as well as for three recognized intervals (A, B, and C) within the Cane Creek.

The EF analysis and mapping indicate there is a narrow, distinct, curvilinear, northwest- to southeast-trending fairway and isolated lobes of moderate to good fluorescence (indicating probable capacity of some oil production if there is adequate porosity and permeability) that are most perspective for future exploration and development in the Cane Creek shale within the Utah portion of the Paradox fold and fault belt. Productive wells (fields), as expected, are distinguished by their generally higher EF ratings. The northeastern portion of the play area shows a regional trend of low EF. Not surprisingly, the EF rating maps show the productive B interval has the greatest potential in areas where several, sparely drilled, large lobes have high EF ratings.

Oil shows can exist within carbonate reservoir seal rocks, although they may not represent mobile hydrocarbons. One common situation for such oil shows in sealing would be associated with organic facies of good source-rock potential. In the A and C intervals, we encountered good EF shows in certain wells within the study area. The EF maps of the A interval show similar lobes those of the B interval that suggest overlooked potential whereas the EF maps of the C interval confirm its standing as a seal with a few possible areas that warrant further investigation. Statistical analysis supports the additional potential identified by the A, B, and C interval EF maps.

Hydrocarbons likely migrated in Cane Creek dolomite, sandstone, and other porous lithologies along regional northwest-trending folds, faults, and fracture zones. This event created the potential oil-prone fairway in the Cane Creek shale that to date is relatively untested.

ACKNOWLEDGMENTS

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This study was carefully reviewed by David Bowen, Montana State University, and Michael D. Vanden Berg, Craig D. Morgan, Mike Hylland, and Richard G. Allis, UGS. Their suggestions and constructive criticism greatly improved the manuscript. Finally, we thank Vicky Clarke, John Good, and the UGS editorial production team for producing a very high-quality publication.

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APPENDICES

APPENDIX A

CANE CREEK SHALE EPIFLUORESCENCE VALUES USED FOR MAPPING EPIFLUORESCENCE TRENDS

Appendix A – Cane Creek Shale Epifluorescence Values Used for Mapping Epifluorescence Trends

Well #	Well Name	Location			Well Type	N	Visual Epifluorescence Rating															
		Section	Township	Range			Cane Creek Highest Value	Cane Creek Average Highest Value	Cane Creek Highest Average Value	Cane Creek Average of Sample Averages	A Interval Highest Value	A Interval Average Highest Value	A Interval Highest Average Value	A Interval Average of Sample Averages	B Interval Highest Value	B Interval Average Highest Value	B Interval Highest Average Value	B Interval Average of Sample Averages	C Interval Highest Value	C Interval Average Highest Value	C Interval Highest Average Value	C Interval Average of Sample Averages
1	Salt Wash Unit 22-34	34	22S	17E	Dry hole	80	1.4	1.1	0.7	0.6	1.4	1.4	0.7	0.7	1.4	1.2	0.6	0.6	1.4	1.1	0.7	0.7
2	Jakey's Ridge 12-3	3	23S	16E	Dry hole	97	2.4	1.9	1.6	1.1	1.8	1.6	1.1	1.1	2.4	2.1	1.6	1.3	2.2	1.8	1.0	0.8
3	Jakey's Ridge 34-15	15	23S	16E	Dry hole	100	2.2	1.6	1.6	0.9	0.8	0.6	0.4	0.3	2.2	2.2	1.4	1.1	ND	ND	ND	ND
4	Salt Wash 1-16	16	23S	17E	Dry hole	71	3.0	2.7	2.4	2.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
5	Gruvers Mesa 1	19	24S	16E	Dry hole	100	2.1	2.0	1.8	1.5	2.1	2.1	1.7	1.7	2.1	2.0	1.8	1.6	2.1	2.0	1.4	1.3
6	Kane Springs Fed 10-1	10	25S	18E	Producing oil well	49	3.0	2.8	2.3	2.2	3.0	3.0	2.3	2.3	2.8	2.6	2.3	2.1	ND	ND	ND	ND
7	Utah 2	18	25S	21E	Dry hole	108	2.5	2.0	2.0	1.5	2.1	1.6	1.4	1.1	2.4	2.2	1.9	1.7	2.5	2.4	1.9	2.0
8	Fed Bowknot 1	30	25S	18E	Dry hole	71	2.6	2.3	2.1	1.9	ND	ND	ND	ND	2.5	2.3	2.0	1.9	2.6	2.5	2.1	2.1
9	Kane Springs Fed 25-19-34-1	34	25S	19E	Producing oil well	149	3.4	2.8	3.1	2.2	H	H	H	H	H	H	H	H	H	H	H	H
10	Cane Creek Unit 26-3	26	25S	19E	Producing oil well	197	3.2	2.3	2.6	1.9	2.3	2.0	2.1	1.7	3.2	2.5	2.6	2.5	2.8	2.2	2.3	1.9
11	Long Canyon 1	9	26S	20E	Producing oil well	39	3.0	2.2	2.0	1.2	2.7	2.1	1.2	0.8	2.8	2.0	1.8	1.1	3.0	2.6	2.0	1.5
12	Mineral Canyon U 1-14	14	26S	19E	PA oil well	65	2.1	1.5	1.7	1.1	1.6	1.3	1.4	1.0	2.1	1.6	1.7	1.3	1.9	1.6	1.4	1.1
13	Federal 1-X	36	26S	20E	Dry hole	43	2.8	2.4	2.2	1.8	2.3	2.3	1.7	1.7	2.4	2.4	1.7	1.7	2.8	2.4	2.2	1.9
14	Featherstone-Federal 9-1	9	27S	20E	Dry hole	100	2.9	2.4	2.1	1.6	2.3	2.1	1.2	1.2	2.9	2.4	2.1	1.7	2.9	2.5	1.8	1.7
15	West Bridger Jack U 3	3	27S	21E	Dry hole	68	1.2	1.0	0.9	0.6	ND	ND	ND	ND	1.2	1.0	0.9	0.7	1.2	1.0	0.7	0.6
16	Cane Creek State 1-36	36	27S	20E	Dry hole	90	3.1	2.5	2.7	1.9	3.1	3.0	2.5	2.4	3.0	2.5	2.7	2.1	2.6	2.3	1.7	1.6
17	Red Rock Unit 1	9	28S	22E	Dry hole	104	2.5	1.8	1.3	1.0	1.1	1.1	0.7	0.7	2.2	2.0	1.2	1.0	2.5	1.8	1.3	1.0
18	Lockhart-Fed 1	22	28S	20E	Dry hole	94	3.0	2.2	2.2	1.7	1.6	1.6	1.5	1.3	2.8	2.2	2.0	1.6	3.0	2.4	2.2	1.9
19	USA Lockhart 1	23	28S	20E	Dry hole	46	1.3	1.1	1.1	0.8	ND	ND	ND	ND	1.0	1.0	0.7	0.7	1.3	1.2	1.1	1.0
20	Government B-1	34	28S	22E	Dry hole	156	3.2	2.3	1.8	1.5	3.2	2.5	1.7	1.4	3.0	2.3	1.8	1.4	2.9	2.2	1.8	1.6
21	Horsehead Unit 1	18	29S	21E	Dry hole	100	3.0	2.1	2.2	1.7	1.7	1.6	1.5	1.4	3.0	2.4	2.2	1.8	2.3	2.2	2.0	1.8
22	Hatch Point 1	14	29S	21E	Producing oil well	38	2.4	2.1	1.9	1.3	ND	ND	ND	ND	2.2	1.9	1.6	1.2	2.4	2.3	1.9	1.5
23	Threemile 12-7	12	29S	21E	Producing oil well	38	2.5	2.1	1.9	1.6	H	H	H	H	H	H	H	H	H	H	H	H
24	La Sal USA 1	19	29S	24E	Dry hole	106	2.0	1.7	1.2	0.8	1.7	1.6	0.7	0.7	1.5	1.4	0.8	0.6	2.0	1.8	1.2	0.9
25	Lisbon D232	32	29.5S	24E	Dry hole	60	0.7	0.5	0.5	0.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
26	Gibson Dome	21	30S	21E	Dry hole	89	2.4	2.2	2.1	1.8	2.2	2.1	1.9	1.8	2.4	2.4	2.1	2.1	2.2	2.2	1.8	1.7
27	Little Valley 2	29	30S	25E	Dry hole	35	1.2	0.8	0.6	0.4	0.6	0.6	0.4	0.4	1.2	1.0	0.6	0.5	ND	ND	ND	ND
28	Hart Point Fed 1	8	31S	22E	Dry hole	77	2.5	2.2	2.1	1.6	2.1	2.1	1.4	1.4	2.5	2.3	2.1	1.7	2.3	2.2	1.6	1.5
29	Winchester 21-1H	21	31S	24E	Dry hole	90	2.0	1.6	1.3	1.0	H	H	H	H	H	H	H	H	H	H	H	H
30	Church Rock Unit 1	26	31S	23E	Dry hole	48	1.8	1.3	1.0	0.7	ND	ND	ND	ND	1.8	1.4	0.8	0.7	1.5	1.2	1.1	0.7
31	Cisco State 36-13	36	31S	24E	Dry hole	133	2.8	2.0	2.3	1.7	2.3	1.5	2.0	1.2	2.8	2.3	2.3	1.9	2.0	1.5	1.9	1.2

Note: See figure 10 for well number locations.

N = number of samples
NA = interval tops not available
ND = no data (no cuttings or cores)
H = horizontal wellbore

APPENDIX B

EPIFLUORESCENCE ANALYSES AND DESCRIPTIONS OF WELL CUTTINGS AND CORES FROM THE CANE CREEK SHALE, PENNSYLVANIAN PARADOX FORMATION, PARADOX FOLD AND FAULT BELT AREA, UTAH

Appendix B – Epifluorescence Analyses and Descriptions of Well Cuttings and Cores from the Cane Creek Shale, Pennsylvanian Paradox Formation, Paradox Fold and Fault Belt Area, Utah

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
		Section, Township, Range				Range	Ave.				
1	Salt Wash 22-34	SENW 34 22S 17E	Grand	9420–30	10	0.0–1.4	0.6	cuttings	A interval – patchy fine to medium crystalline dolomite, often in a black shaly matrix.		
1	Salt Wash 22-34	SENW 34 22S 17E	Grand	9430–40	10	0.4–1.3	0.7	cuttings	A interval – patchy fine to medium crystalline dolomite, often in a black shaly matrix; one sample of bryozoan packstone to framestone fabric.		
1	Salt Wash 22-34	SENW 34 22S 17E	Grand	9440–50	10	0.4–1.0	0.6	cuttings	B interval – fine to medium crystalline dolomitic mudstone/wackestone fabric, somewhat silty.		
1	Salt Wash 22-34	SENW 34 22S 17E	Grand	9450–60	10	0.3–0.7	0.5	cuttings	B interval – peloidal packstone/grainstone fabric, and dolomitic and limey bryozoan grainstone/framestone fabric containing minor dolomitic shale.		
1	Salt Wash 22-34	SENW 34 22S 17E	Grand	9460–70	10	0.2–1.4	0.7	cuttings	C interval – finely crystalline dolomitic mudstone and a fragmental grainstone/framestone fabric, slightly dolomitic.		
1	Salt Wash 22-34	SENW 34 22S 17E	Grand	9470–80	10	0.3–1.1	0.7	cuttings	C interval – microcrystalline dolomitic mudstone and silty medium crystalline dolomitic mudstone/wackestone fabric.		
1	Salt Wash 22-34	SENW 34 22S 17E	Grand	9480–90	10	0.3–0.9	0.6	cuttings	C interval – silty, fossiliferous dolomitic wackestone to packstone fabric containing slightly dolomitic bryozoan.		
1	Salt Wash 22-34	SENW 34 22S 17E	Grand	9490–9500	10	0.3–1.0	0.6	cuttings	C interval – microcrystalline dolomitic mudstone and fossiliferous medium crystalline dolomitic wackestone fabric.		
2	Jakey's Ridge 12-3	SWNW 3 23S 16E	Emery	7990–8000	7	0.4–1.3	1	cuttings	A interval – patchy, fine to medium crystalline dolomite in a black shale matrix.		
2	Jakey's Ridge 12-3	SWNW 3 23S 16E	Emery	8000–10	10	0.4–1.8	1.1	cuttings	A interval – silty dolomitic mudstone and slightly dolomite fossiliferous packstone to grainstone fabrics containing possible bryozoans.		
2	Jakey's Ridge 12-3	SWNW 3 23S 16E	Emery	8010–20	10	0.4–1.5	0.9	cuttings	B interval – silty dolomitic mudstone and a slightly dolomitic fossiliferous packstone/wackestone fabric.		
2	Jakey's Ridge 12-3	SWNW 3 23S 16E	Emery	8020–30	10	0.4–2.0	1.1	cuttings	B interval – slightly silty, finely crystalline dolomitic mudstone and medium crystalline dolomitic packstone to wackestone fabrics containing possible fossil fragments.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
2	Jakey's Ridge 12-3	SWNW 3 23S 16E	Emery	8030–40	10	0.4–2.4	1.4	cuttings	B interval – mixed lithologies of slightly silty shale and dolomitized skeletal grainestone/packstone fabric containing small possible molds, and dolomitized microbialite.	X	X
2	Jakey's Ridge 12-3	SWNW 3 23S 16E	Emery	8040–50	10	0.9–2.2	1.6	cuttings	B interval – silty dolomitic mudstone to wackestone fabrics; possible carbonate or fossil fragments.	X	X
2	Jakey's Ridge 12-3	SWNW 3 23S 16E	Emery	8050–60	10	0.5–2.4	1.4	cuttings	B interval – slightly to very silty dolomitic mudstone; no fossil fragments.	X	X
2	Jakey's Ridge 12-3	SWNW 3 23S 16E	Emery	8060–70	10	0.3–2.2	1	cuttings	C interval – silty dolomitic mudstone and medium crystalline dolomitic wackestone/packstone fabric.		
2	Jakey's Ridge 12-3	SWNW 3 23S 16E	Emery	8070–80	10	0.3–1.8	0.8	cuttings	C interval – silty, finely crystalline dolomitic mudstone and shaley mudstone.		
2	Jakey's Ridge 12-3	SWNW 3 23S 16E	Emery	8080–90	10	0.2–1.3	0.7	cuttings	C interval – slightly silty black shale and argillaceous silty dolomitic mudstone.		
3	Jakey's Ridge 34-15	SWSE 15 23S 16E	Emery	7640–50	10	0.1–0.5	0.2	cuttings	A interval – black, highly organic shale; no visible dolomite or silt.		
3	Jakey's Ridge 34-15	SWSE 15 23S 16E	Emery	7650–60	10	0.1–0.6	0.4	cuttings	A interval – black organic-rich shale including rare patches of very finely crystalline dolomite.		
3	Jakey's Ridge 34-15	SWSE 15 23S 16E	Emery	7660–70	10	0.1–0.8	0.4	cuttings	A interval – black organic-rich shale including rare patches of very finely crystalline dolomite.		
3	Jakey's Ridge 34-15	SWSE 15 23S 16E	Emery	7670–80	10	0.2–1.6	0.8	cuttings	B interval – fine to medium crystalline dolomite, slightly silty; wackestone/mudstone fabric showing no visible porosity and very dim fluorescence.		
3	Jakey's Ridge 34-15	SWSE 15 23S 16E	Emery	7680–90	10	0.3–2.1	1.1	cuttings	B interval – interbedded, fine to medium crystalline dolomite; grainstone/packstone fabric and good fluorescence. Occasionally silty and organic-rich, finely crystalline dolomite showing dim fluorescence.	X	X
3	Jakey's Ridge 34-15	SWSE 15 23S 16E	Emery	7690–7700	10	0.3–2.1	1	cuttings	B interval – interbedded finely crystalline dolomite; grainstone/packstone fabric showing moderate fluorescence and argillaceous silty finely crystalline dolomite showing very dim fluorescence.	X	X
3	Jakey's Ridge 34-15	SWSE 15 23S 16E	Emery	7700–10	10	0.2–2.2	1.4	cuttings	B interval – silty microcrystalline dolomite; mudstone/wackestone fabric showing fair fluorescence, and interbedded with argillaceous finely crystalline dolomite showing dim fluorescence.		
3	Jakey's Ridge 34-15	SWSE 15 23S 16E	Emery	7710–20	10	0.3.–2.2	1.3	cuttings	B interval – very silty dolomite to dolomitic siltstone, patchy and highly variable fluorescence; no visible porosity.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
		Section, Township, Range				Range	Ave.				
3	Jakey's Ridge 34-15	SWSE 15 23S 16E	Emery	7720–30	10	0.5–1.9	1.1	cuttings	B interval – dolomitic siltstone consisting of low visible porosity and dim to moderate fluorescence and argillaceous, slightly dolomitic siltstone consisting of very low fluorescence.		
3	Jakey's Ridge 34-15	SWSE 15 23S 16E	Emery	7730–40	10	0.6–2.0	1.6	cuttings	B interval – slightly dolomitic siltstone to highly silty dolomite; variable visible porosity and fluorescence.		
4	Salt Wash 1-16	NESW 16 23S 17E	Grand	8250–60	10	1.8–3.0	2.1	cuttings	Interval tops not available – medium crystalline dolomite throughout microbial grainstone fabric showing visible porosity throughout; fair to very good oil fluorescence.	X	X
4	Salt Wash 1-16	NESW 16 23S 17E	Grand	8260–70	10	1.8–2.6	2.1	cuttings	Interval tops not available – medium crystalline dolomite; grainstone/packstone fabric showing good uniform fluorescence throughout, some microfractures displaying fluorescence.	X	X
4	Salt Wash 1-16	NESW 16 23S 17E	Grand	8270–80	8	1.9–2.9	2.1	cuttings	Interval tops not available – fine to medium crystalline dolomite showing variable fluorescence and porosity; microbial and wackestone/packstone fabric.	X	X
4	Salt Wash 1-16	NESW 16 23S 17E	Grand	8280–90	10	2.0–2.8	2.3	cuttings	Interval tops not available – medium crystalline dolomite and grainstone microbial fabrics; good oil fluorescence.	X	X
4	Salt Wash 1-16	NESW 16 23S 17E	Grand	8290–8300	8	1.5–2.4	2	cuttings	Interval tops not available – fine to medium dolomite composed of wackestone/packstone and possible microbial fabrics; low visible porosity.		
4	Salt Wash 1-16	NESW 16 23S 17E	Grand	8300–10	7	1.5–2.3	1.9	cuttings	Interval tops not available – medium crystalline dolomite; microbial fabric showing patches of interlocking anhydrite crystals and argillaceous matrix.		
4	Salt Wash 1-16	NESW 16 23S 17E	Grand	8310–20	9	1.5–2.2	1.9	cuttings	Interval tops not available – fine to medium crystalline dolomite showing patches of argillaceous matrix, low visible porosity, and patchy fluorescence.		
4	Salt Wash 1-16	NESW 16 23S 17E	Grand	8320–30	9	1.3–3.0	2.4	cuttings	Interval tops not available – silty, fine to medium crystalline dolomite; grainstone/packstone/wackestone fabric showing variable anhydrite plugging and moderate to bright oil fluorescence.	X	X
5	Gruvers Mesa 1	SENW 19 24S 16E	Emery	7185–95	10	1.1–2.0	1.7	cuttings	A interval – fine to medium crystalline dolomite with terrigenous silt, generally low visible porosity; mudstone/wackestone fabric.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
		Section, Township, Range				Range	Ave.				
5	Gruvers Mesa 1	SENW 19 24S 16E	Emery	7195–7205	10	1.0–2.1	1.6	cuttings	A interval – finely crystalline dolomite, occasionally silty to argillaceous showing no visible porosity; mudstone fabric having generally dim fluorescence.		
5	Gruvers Mesa 1	SENW 19 24S 16E	Emery	7205–15	10	1.0–2.1	1.5	cuttings	B interval – silty, finely crystalline dolomite consisting of variable argillaceous content interbedded with fine to medium crystalline dolomite; intercrystalline porosity.		
5	Gruvers Mesa 1	SENW 19 24S 16E	Emery	7215–25	10	1.1–2.1	1.6	cuttings	B interval – finely crystalline dolomite, slightly silty; packstone/wackestone fabric showing very low visible porosity and some disseminated pyrite.		
5	Gruvers Mesa 1	SENW 19 24S 16E	Emery	7225–35	10	1.5–2.1	1.8	cuttings	B interval – fine to medium crystalline dolomite with low visible porosity; occasional silty argillaceous interbeds.		
5	Gruvers Mesa 1	SENW 19 24S 16E	Emery	7235–45	10	0.5–1.8	1.3	cuttings	B interval – silty to argillaceous dolomite, finely crystalline showing no visible porosity; mudstone.		
5	Gruvers Mesa 1	SENW 19 24S 16E	Emery	7245–55	10	0.5–2.0	1.3	cuttings	C interval – fine to medium crystalline dolomite showing no visible porosity, dim fluorescence, and occasionally argillaceous.		
5	Gruvers Mesa 1	SENW 19 24S 16E	Emery	7255–65	10	0.8–2.0	1.4	cuttings	C interval – fine to medium crystalline dolomite containing some visible intercrystalline porosity and occasionally silty to argillaceous; mudstone.		
5	Gruvers Mesa 1	SENW 19 24S 16E	Emery	7265–75	10	0.8–2.1	1.4	cuttings	C interval – fine to medium crystalline dolomite consisting of some visible intercrystalline porosity and occasionally silty to argillaceous; mudstone.		
5	Gruvers Mesa 1	SENW 19 24S 16E	Emery	7275–90	10	0.9–1.8	1.2	cuttings	C interval – silty to argillaceous dolomite and fine crystalline dolomite, mudstone fabric, and no visible porosity.		
6	Kane Springs Federal 10-1	NWSE 10 25S 18E	Grand	8890–8900	10	1.9–3.0	2.3	cuttings	A interval – silty dolomite to clean, fine crystalline dolomite showing patchy but very bright fluorescence; grainstone/packstone fabric(?).		
6	Kane Springs Federal 10-1	NWSE 10 25S 18E	Grand	8900–10	10	2.0–2.9	2.3	cuttings	A interval – fine to medium crystalline dolomite, generally laminated containing frequent tubular microbial textures, good visible pores within the microbialites, and some interbedded silty and anhydrite intervals; good bright fluorescence throughout.	X	X

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
6	Kane Springs Federal 10-1	NWSE 10 25S 18E	Grand	8910–20	10	1.8–2.5	2.1	cuttings	B interval – slightly silty, fine to medium crystalline dolomite showing possible microbialite structures; lower visible porosity than previous samples.	X	X
6	Kane Springs Federal 10-1	NWSE 10 25S 18E	Grand	8920–30	9	1.8–2.8	2.3	cuttings	B interval – fine to medium crystalline dolomite, slightly silty displaying occasional laminated microbial textures; some interbedded anhydrite.		
6	Kane Springs Federal 10-1	NWSE 10 25S 18E	Grand	8930–40	10	0.6–2.6	1.8	cuttings	B interval – interbedded, fine to medium dolomite, silty wackestone/packstone fabric and argillaceous, organic, fine dolomite showing very dim fluorescence.		
7	Utah 2	NWSW 36 31S 24E	Grand	7580–90	10	0.5–1.9	1.3	cuttings	A interval – silty shale with little to no dolomite; very low porosity showing patchy fluorescence.		
7	Utah 2	NWSW 36 31S 24E	Grand	7590–7600	10	0.9–2.1	1.4	cuttings	A interval – siltstone consisting of variable amounts of fine to medium dolomite clusters exhibiting patchy fluorescence.	X	X
7	Utah 2	NWSW 36 31S 24E	Grand	7600–10	8	0.5–1.2	0.8	cuttings	A interval – silty shale having very little dolomite, no visible porosity, and generally dim fluorescence.		
7	Utah 2	NWSW 36 31S 24E	Grand	7610–20	10	0.5–1.2	0.9	cuttings	A interval – black shale containing small patches of fine dolomite and silty dolomite; no visible porosity.		
7	Utah 2	NWSW 36 31S 24E	Grand	7620–30	7	0.7–2.1	1.4	cuttings	B interval – patches of fine to medium dolomite interbedded with silty shale; highly variable fluorescence.		
7	Utah 2	NWSW 36 31S 24E	Grand	7630–40	9	0.9–2.1	1.4	cuttings	B interval – fine to medium crystalline dolomite showing fair to good fluorescence; packstone/wackestone fabric interbedded with slightly dolomitic shale.		
7	Utah 2	NWSW 36 31S 24E	Grand	7640–50	10	1.1–2.0	1.7	cuttings	B interval – fine to medium crystalline dolomite showing fair to good fluorescence; packstone/wackestone fabric interbedded with slightly dolomitic shale.		
7	Utah 2	NWSW 36 31S 24E	Grand	7650–60	10	1.0–2.1	1.7	cuttings	B interval – fine to medium crystalline dolomite surrounded by patches of argillaceous and organic matrix; no visible porosity and patchy fluorescence.		
7	Utah 2	NWSW 36 31S 24E	Grand	7660–90					No cuttings.		
7	Utah 2	NWSW 36 31S 24E	Grand	7690–7700	8	1.0–2.4	1.9	cuttings	B interval – fine to medium crystalline dolomite showing very good fluorescence and some visible intercrystalline pores interbedded with silty shale.	X	X

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
7	Utah 2	NWSW 36 31S 24E	Grand	7700–10	7	1.5–2.3	1.9	cuttings	B interval – fine to medium crystalline dolomite consisting of variable intercrystalline porosity and good fluorescence, interbedded with silty shale.	X	X
7	Utah 2	NWSW 36 31S 24E	Grand	7710–20	10	1.0–2.3	1.9	cuttings	C interval – fine to medium crystalline dolomite showing of variable intercrystalline porosity and good fluorescence, interbedded with silty shale.		
7	Utah 2	NWSW 36 31S 24E	Grand	7720–30	9	1.0–2.5	2	cuttings	C interval – mostly finely crystalline dolomite showing variable fluorescence; mudstone/wackestone fabric containing scattered silt grains.		
8	Federal Bowknot 1	NESE 30 25S 18E	Grand	6940–50	10	1.0–2.2	1.6	cuttings	B interval – dolomite and dolomitic shale; dolomite crystal aggregates also present.	X	X
8	Federal Bowknot 1	NESE 30 25S 18E	Grand	6950–60	10	1.5–2.0	1.8	cuttings	B interval – dolomite and dolomitic shale.		
8	Federal Bowknot 1	NESE 30 25S 18E	Grand	6960–70	9	0.7–2.5	2	cuttings	B interval – mostly dolomite and some slightly silty dolomitic shale. Rhombic dolomite clusters and dolomite contain visible intercrystalline porosity.	X	X
8	Federal Bowknot 1	NESE 30 25S 18E	Grand	6970–75	7	1.7–2.4	2	cuttings	B interval – silty dolomite and complete dolomite.	X	X
8	Federal Bowknot 1	NESE 30 25S 18E	Grand	6975–80	7	1.3–2.2	2	cuttings	B interval – mostly dolomite and dolomitic shale.		
8	Federal Bowknot 1	NESE 30 25S 18E	Grand	6980–88	10	1.5–2.2	2	cuttings	B interval – dolomitic shale (missing cuttings from 6988–7000').		
8	Federal Bowknot 1	NESE 30 25S 18E	Grand	7000–10	9	1.6–2.4	2	cuttings	C interval – microcrystalline dolomite.	X	X
8	Federal Bowknot 1	NESE 30 25S 18E	Grand	7015–20	9	1.5–2.6	2.1	cuttings	C interval – mostly dolomitic shale (missing cuttings from 7010–7015').		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7550–60	6	2.4–3.0	2.7	cuttings	Horizontal well – dolomitic shale to silty dolomite.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7560–70	7	2.8–3.2	2.9	cuttings	Horizontal well – dolomite and silty dolomite.	X	X
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7570–80	9	2.9–3.4	2.9	cuttings	Horizontal well – microcrystalline dolomite and anhydritic dolomite; oil films.	X	X
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7580–90	6	1.8–3.2	2.6	cuttings	Horizontal well – honeycomb remnants of microbial filaments(?).	X	X
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7590–7600	5	1.5–2.6	2	cuttings	Horizontal well – slightly silty shale and very minor dolomite.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7600–10	10	1.5–3.0	2.3	cuttings	Horizontal well – silty dolomite and microlaminated microbial dolomite.	X (see figure 11F)	X
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7610–20	9	1.6–2.4	1.9	cuttings	Horizontal well – shale to silty shale.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
		Section, Township, Range				Range	Ave.				
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7620–30	10	0.8–3.0	2	cuttings	Horizontal well – dolomitic shale, shale, and microbial dolomite.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7630–40	6	1.8–2.3	2.1	cuttings	Horizontal well – silty and slightly dolomitic shale.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7640–50	7	1.5–2.4	1.9	cuttings	Horizontal well – slightly dolomitic shale.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7650–60	7	2.0–2.9	2.4	cuttings	Horizontal well – dolomite to dolomitic shale.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7660–70	6	1.5–3.0	2.2	cuttings	Horizontal well – microcrystalline dolomite and dolomitic shale.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7670–80	5	2.0–3.3	2.5	cuttings	Horizontal well – dolomite and silty shale.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7680–90	7	1.8–2.5	2.1	cuttings	Horizontal well – silty shale to dolomitic silty shale.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7690–7700	5	0.5–2.8	1.9	cuttings	Horizontal well – mostly silty shale to slightly dolomitic shale.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7700–10	10	1.5–2.6	2	cuttings	Horizontal well – slightly dolomitic shale.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7710–20	9	1.8–3.0	2.3	cuttings	Horizontal well – silty dolomitic shale.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7720–30	6	2.8–3.3	3.1	cuttings	Horizontal well – mostly dolomite and silty shale.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7730–40	5	1.2–2.6	1.6	cuttings	Horizontal well – patchy fluorescence in dolomitic mudstone; somewhat shaly/argillaceous matrix.	X	X
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7740–50	6	2.3–2.9	2.7	cuttings	Horizontal well – patchy dolomitic mudstone and argillaceous partings.	X	X
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7750–60	5	0.3–2.5	1.4	cuttings	Horizontal well – interbedded black shale and patchy fluorescent dolomite.		
9	Kane Springs 25-19-34-1	NWSE 34 25S 19E	Grand	7760–70	3	1.0–1.5	1.2	cuttings	Horizontal well – mostly shale with small patches of dolomite crystalline clusters.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7388.9	9	1.3–2.1	1.8	core	A interval – medium crystalline dolomite containing rare floating silt grains and low visible porosity; mudstone/wackestone fabric.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7394.5	10	1.7–2.2	2	core	A interval – finely crystalline dolomite, wackestone/mudstone fabric, and very low visible porosity partially due to calcite between the dolomite crystals.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7398.4	10	0.3–1.3	0.7	core	A interval – black, organic finely crystalline dolomite; mudstone fabric containing argillaceous patches, and rare floating silt grains.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7403.1	10	1.3–2.1	1.8	core	A interval – slightly silty, finely crystalline dolomite; mudstone fabric having no visible of porosity but patches of anhydrite.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
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10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7408.9	10	1.9–2.3	2.1	core	A interval – fine to medium crystalline dolomite, slightly silty, showing probable microbial structures; fair visible porosity and fluorescence.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7410.4	10	2.1–2.6	2.2	core	B interval – silt to silty dolomite and a medium crystalline grainstone fabric or microbialite consisting of good intercrystalline porosity.	X	X
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7413.2	10	0.5–1.7	1.1	core	B interval – black organic-rich, finely crystalline dolomite; mudstone showing very low visible porosity and dim fluorescence.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7416.2	10	1.3–2.2	1.7	core	B interval – fine to medium crystalline dolomite, packstone/grainstone fabric, and poor visible porosity; some anhydrite plugging.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7419.5	10	1.8–2.1	2	core	B interval – fine to medium crystalline dolomite, mudstone/wackestone fabric showing poor visible porosity and patchy fluorescence.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7428.1	10	2.2–3.2	2.6	core	B interval – medium crystalline and silty dolomite having a probable microbialite texture; excellent intercrystallline porosity and bright fluorescence.	X	X
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7429.8	10	2.0–2.8	2.3	core	B interval – fine to medium crystalline dolomite, mudstone/wackestone fabric showing poor visible porosity and patchy fluorescence.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7433.3	10	0.7–2.1	1.4	core	B interval – slightly silty limestone, mudstone showing no visible porosity and patchy poor fluorescence.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7437.5	10	2.2–3.0	2.6	core	B interval – slightly silty fine to medium crystalline dolomite displaying probable microbialite textures; good visible porosity and fluorescence.	X	X
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7440.5	10	2.0–2.6	2.2	core	B interval, fine to medium crystalline dolomite, wackestone/packstone, microbial with variable but frequently good porosity, occasional silt grains and silty dolomite	X	X
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7445.1	10	2.0–3.0	2.3	core	B interval – medium crystalline dolomite, microbial grainstone/packstone fabric showing rare floating silt grains and good intercrystalline and interparticle pores.	X	X
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7453.5	10	2.0–2.6	2.3	core	C interval – fine to medium crystalline dolomite, wackestone/mudstone fabric, some black organic-rich shale, and generally low visible porosity but good bright fluorescence; no silt grain observed.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
		Section, Township, Range				Range	Ave.				
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7456	10	2.1–2.8	2.3	core	C interval – medium crystalline to silty dolomite showing excellent visible intercrystalline porosity; probable microbial textures throughout.	X	X
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7464.8	8	0.3–0.9	0.6	core	C interval –black, organic finely crystalline dolomite to dolomitic shale, no visible porosity, and rare scattered silt grains.		
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7469.2	10	1.9–2.5	2.1	core	C interval – medium crystalline to silty/argillaceous dolomite showing microlaminated microbialite structures and good visible intercrystalline porosity.	X	X
10	Cane Creek Unit 26-3	NESW 26 25S 19E	Grand	7470.4	10	1.8–2.2	2	core	C interval – calcareous dolomite to dolomitic limestone consisting of highly variable visible porosity and fluorescence, some microbial textures as well as mudstone/wackestone fabric; possible baffle but with fair to good fluorescence.		
11	Long Canyon 1	SENW 9 25S 20E	Grand	7020–30	4	0.0–1.5	0.4	cuttings	A interval – all samples are anhydrite; white to clear.		
11	Long Canyon 1	SENW 9 25S 20E	Grand	7030–40	4	0.5–2.7	1.2	cuttings	A interval – weakly fluorescing shale and one medium crystalline dolomite; wackestone to packstone(?) fabric.	X	X
11	Long Canyon 1	SENW 9 25S 20E	Grand	7040–50	5	0.0–0.3	0.2	cuttings	B interval – black shale, no fluorescence.		
11	Long Canyon 1	SENW 9 25S 20E	Grand	7050–60	5	0.3–2.4	1.1	cuttings	B interval – black shale containing no fluorescence, and medium crystalline dolomite that is slightly anhydritic.		
11	Long Canyon 1	SENW 9 25S 20E	Grand	7060–70	4	0.2–2.8	1.3	cuttings	B interval – black shale and medium crystalline dolomite showing apparent intercrystalline porosity.	X	X
11	Long Canyon 1	SENW 9 25S 20E	Grand	7070–80	4	0.7–2.4	1.8	cuttings	B interval – slightly dolomitized skeletal grainstone fabric containing possible ostracods.	X	X
11	Long Canyon 1	SENW 9 25S 20E	Grand	7080–95					No cuttings		
11	Long Canyon 1	SENW 9 25S 20E	Grand	7095–7100	5	1.3–2.8	2	cuttings	C interval – micro colonial fossil, possible bryozoan.	X	X
11	Long Canyon 1	SENW 9 25S 20E	Grand	7100–10					No cuttings		
11	Long Canyon 1	SENW 9 25S 20E	Grand	7110–15	4	0.5–3.0	1.4	cuttings	C interval – skeletal grainstone fabric composed of colonial bryozoan fragments.	X	
11	Long Canyon 1	SENW 9 25S 20E	Grand	7115–35	4	0.1–2.0	1	cuttings	C interval – black shale and medium to coarsely crystalline dolomite.		
12	Mineral Canyon 1-14	SWSE 14 26S 19E	Grand	7330–40	5	1.1–1.6	1.4	cuttings	A interval – dolomitic mudstone to wackestone fabrics, clean, and dull uniform fluorescence.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
		Section, Township, Range				Range	Ave.				
12	Mineral Canyon 1-14	SWSE 14 26S 19E	Grand	7340–50	10	0.3–1.0	0.6	cuttings	A interval – very small samples.		
12	Mineral Canyon 1-14	SWSE 14 26S 19E	Grand	7350–60	9	0.3–0.8	0.6	cuttings	B interval – slightly argillaceous dolomitic wackestone to packstone fabrics; fine to medium crystal size.		
12	Mineral Canyon 1-14	SWSE 14 26S 19E	Grand	7360–70	7	1.1–1.8	1.5	cuttings	B interval – medium crystalline dolomite showing intercrystalline porosity; dull fluorescence exhibits some nonfluorescent argillaceous patches.	X	X
12	Mineral Canyon 1-14	SWSE 14 26S 19E	Grand	7370–80					No samples		
12	Mineral Canyon 1-14	SWSE 14 26S 19E	Grand	7380–90	10	1.2–2.1	1.7	cuttings	B interval – highly dolomitic shale consisting of well-developed dolomite crystals and microporosity.	X (see figure 11C)	X (see figure 19A)
12	Mineral Canyon 1-14	SWSE 14 26S 19E	Grand	7390–7400	7	0.1–1.8	1	cuttings	C interval – mostly finely crystalline dolomitic mudstone, moderately argillaceous.		
12	Mineral Canyon 1-14	SWSE 14 26S 19E	Grand	7400–10	7	1.1–1.9	1.4	cuttings	C interval – patchy, microcrystalline dolomitic mudstone.		
12	Mineral Canyon 1-14	SWSE 14 26S 19E	Grand	7410–20	10	0.5–1.2	0.8	cuttings	C interval – very small samples.		
13	Federal 1-X	NESE 36 26S 20E	San Juan	6520–30	9	0.5–2.3	1.7	cuttings	A interval – shale containing isolated clusters of dolomite.		
13	Federal 1-X	NESE 36 26S 20E	San Juan	6530–40	6	0.5–2.4	1.7	cuttings	B interval – microfractured dolomitic shale (no cuttings, 6540–6580'; all halite, 6580–6590'; no cuttings, 6590–6610').	X	X
13	Federal 1-X	NESE 36 26S 20E	San Juan	6610–20	10	1.5–2.3	1.9	cuttings	C interval – mostly shale, slightly dolomitic.		
13	Federal 1-X	NESE 36 26S 20E	San Juan	6620–30	8	1.0–2.1	1.7	cuttings	C interval – silty and slightly dolomitic shale containing aggregates of rhombic dolomite.	X	X
13	Federal 1-X	NESE 36 26S 20E	San Juan	6630–40	10	1.8–2.8	2.2	cuttings	C interval – highly dolomitic shale, anhydritic dolomite, and crystalline dolomite containing anhydrite clusters (no cuttings, 6640–6685').	X	X
14	Featherstone 9-1	NENE 9 27S 20E	San Juan	5790–5800	10	0.3–1.8	1.1	cuttings	A interval – black shale containing clusters of fine to medium dolomite crystals and dolomitic siltstone.		
14	Featherstone 9-1	NENE 9 27S 20E	San Juan	5800–10	10	0.5–2.3	1.2	cuttings	A interval – dolomitic siltstone and fine to medium crystalline mudstone, occasionally argillaceous.	X	X
14	Featherstone 9-1	NENE 9 27S 20E	San Juan	5810–20	10	1.1–2.3	1.8	cuttings	B interval – dolomitic siltstone and fossiliferous dolomitic packstone/wackestone fabric; fine to medium crystalline.	X	X
14	Featherstone 9-1	NENE 9 27S 20E	San Juan	5820–30	10	0.7–1.5	1	cuttings	B interval – dolomitic siltstone and fine to medium crystalline dolomitic wackestone/packstone fabric.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
		Section, Township, Range				Range	Ave.				
14	Featherstone 9-1	NENE 9 27S 20E	San Juan	5830–40	10	1.7–2.8	2.1	cuttings	B interval – dolomitic siltstone to silty dolomite, some of which have clusters of medium crystalline dolomite; no fossils observed.	X	X
14	Featherstone 9-1	NENE 9 27S 20E	San Juan	5840–50	10	1.5–2.9	1.9	cuttings	B interval – medium crystalline interlocking dolomite containing modest intercrystalline porosity; some variable argillaceous dolomite.	X	X
14	Featherstone 9-1	NENE 9 27S 20E	San Juan	5850–60	10	1.1–2.7	1.8	cuttings	C interval – fine to medium crystalline dolomite, mudstone to wackestone fabric, and argillaceous dolomite containing medium crystalline dolomite clusters.	X	X
14	Featherstone 9-1	NENE 9 27S 20E	San Juan	5860–70	10	0.9–2.9	1.7	cuttings	C interval – medium crystalline dolomite, wackestone/packstone fabric, and shale containing silt and clusters of medium crystalline dolomite.	X	X
14	Featherstone 9-1	NENE 9 27S 20E	San Juan	5870–80	10	0.6–2.3	1.6	cuttings	C interval – shaly and silty dolomite showing occasional cleaner fossiliferous wackestone to packstone fabrics, and fine to medium crystalline dolomite.	X	X
14	Featherstone 9-1	NENE 9 27S 20E	San Juan	5880–95	10	1.3–2.0	1.7	cuttings	C interval – mostly shale and silty shale containing fine to medium dolomite crystal clusters.		
15	West Bridger Jack U 3	SESW 3 27S 21E	San Juan	5900–10	10	0.6–1.1	0.9	cuttings	B interval – finely dolomitic shale.		
15	West Bridger Jack U 3	SESW 3 27S 21E	San Juan	5910–20	10	0.3–0.8	0.6	cuttings	B interval – dolomitic shale; medium size cuttings.		
15	West Bridger Jack U 3	SESW 3 27S 21E	San Juan	5920–30	10	0.2–1.2	0.5	cuttings	B interval – dolomitic shale.	X	X
15	West Bridger Jack U 3	SESW 3 27S 21E	San Juan	5930–40	10	0.1–0.5	0.4	cuttings	C interval – slightly silty shale.		
15	West Bridger Jack U 3	SESW 3 27S 21E	San Juan	5940–50	10	0.3–1.1	0.7	cuttings	C interval – finely crystalline dolomitic shale.		X (see figure 19E)
15	West Bridger Jack U 3	SESW 3 27S 21E	San Juan	5950–60	8	0.1–1.2	0.4	cuttings	C interval – mostly black shale, minor dolomite.		
15	West Bridger Jack U 3	SESW 3 27S 21E	San Juan	5960–70	10	0.1–1.1	0.7	cuttings	C interval – mostly black shale.		X (see figure 19F)
16	Cane Creek State 1-36	NWSE 36 27S 20E	San Juan	7000–10	6	1.8–2.8	2.2	cuttings	A interval – microbial dolomite, containing good intercrystalline porosity, and occasional argillaceous intervals.	X	X
16	Cane Creek State 1-36	NWSE 36 27S 20E	San Juan	7010–20	9	2.0–3.1	2.5	cuttings	A interval – porous fine to medium crystalline dolomitic microbial boundstone fabric to silty dolomite; variable amounts of anhydrite and bitumen present.	X	X
16	Cane Creek State 1-36	NWSE 36 27S 20E	San Juan	7020–30	7	1.5–3.0	2.2	cuttings	B interval – silty dolomite, fine to medium crystal size, dolomitic mudstone; microbialite(?).		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
16	Cane Creek State 1-36	NWSE 36 27S 20E	San Juan	7030–40	10	2.0–2.9	2.7	cuttings	B interval – very silty dolomitic mudstone to wackestone fabric showing micro-stylolites and probable micro fractures.		
16	Cane Creek State 1-36	NWSE 36 27S 20E	San Juan	7040–50	9	1.0–2.2	1.8	cuttings	B interval – black argillaceous dolomite having a generally non fluorescence matrix except where fine to medium crystalline dolomite crystal occur; mudstone/wackestone fabric.		
16	Cane Creek State 1-36	NWSE 36 27S 20E	San Juan	7050–60	10	1.3–1.9	1.6	cuttings	B interval – laminated dolomitic shale showing fluorescence only in some finely crystalline dolomite layers; shale, possibly silty in some laminae.		
16	Cane Creek State 1-36	NWSE 36 27S 20E	San Juan	7060–70	9	1.1–2.3	1.7	cuttings	C interval – fine to medium crystalline dolomite, some intercrystal pores, and occasionally argillaceous; maybe peloidal packstone/wackestone fabric, bitumen present.	X	X
16	Cane Creek State 1-36	NWSE 36 27S 20E	San Juan	7070–80	10	0.9–2.1	1.4	cuttings	C interval – fine to medium crystalline dolomite, occasionally argillaceous, and hints of microporous microbialite textures; bitumen present.	X	X
16	Cane Creek State 1-36	NWSE 36 27S 20E	San Juan	7080–90	10	0.6–2.6	1.4	cuttings	C interval – interbedded non-fluorescing shale and fine to medium crystalline dolomite showing porosity and fluorescence; bitumen present.	X	X
16	Cane Creek State 1-36	NWSE 36 27S 20E	San Juan	7090–7100	10	1.1–2.0	1.7	cuttings	C interval – silty, peloidal packstone/grainstone fabric showing variable fluorescence as well as dolomitic shale showing only low fluorescence.		
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6790–6800	9	0.3–1.1	0.7	cuttings	A interval – black organic shale showing silty and dolomitic patches; no visible porosity or microbial structure.		
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6800–10	8	0.3–1.9	1	cuttings	B interval – finely crystalline dolomite, packstone/grainstone fabric consisting of small hard peloids and possibly coated grains; low visible porosity.		
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6810–20	8	0.3–2.0	1.2	cuttings	B interval – medium crystalline dolomite, often with good rhombic crystal shape; patches of argillaceous matrix have no visible porosity.		
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6820–30	9	0.3–2.2	0.7	cuttings	B interval – fine to medium dolomite having an occasional microbial fabric interbedded with slightly dolomitic shale; microbial dolomite shows some visible porosity.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
		Section, Township, Range				Range	Ave.				
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6830–40	10	0.3–1.3	0.7	cuttings	C interval – fine to medium crystalline dolomite, wackestone/packstone fabric, and no visible porosity, interbedded with slightly dolomitic black shale.		
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6840–50	8	0.5–1.5	1	cuttings	C interval – fine to medium crystalline dolomitic showing probable good microbialite structures and patches of argillaceous dolomite.		
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6850–60	9	0.7–2.2	1.3	cuttings	C interval – fine to medium crystalline dolomite, traces of anhydrite, and packstone/grainstone fabric interbedded with slightly dolomitic argillaceous intervals; some bitumen.	X	X
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6860–70	7	0.3–2.4	1.1	cuttings	C interval – slightly silty and argillaceous microcrystalline dolomite including some tight limestone, generally low visible porosity; packstone/wackestone fabric. Anhydrite cement and bitumen are present.	X	X
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6870–80	10	0.4–1.7	1.1	cuttings	C interval – fine to medium dolomite showing possible microbial fabric and patches of argillaceous material.		
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6880–90	8	0.3–2.5	1.1	cuttings	C interval – fine to medium dolomite, packstone/grainstone/mudstone fabric, and occasional argillaceous patches.	X	
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6890–6900	10	0.3–2.1	1.2	cuttings	C interval – fine to medium dolomite consisting of lumpy microbial structures and grainstone/packstone fabric interbedded with dolomitic shale.		
17	Red Rock Unit 1	NWNE 9 28S 22E	San Juan	6900–10	8	0.3–0.8	0.5	cuttings	C interval – black organic-rich shale containing little to no dolomite; possible microfractures with minor fluorescence.		
18	Gulf-Aztec-Lockhart-Fed 1	SWSW 22 28S 20E	San Juan	4765–70	8	0.2–1.5	1	cuttings	A interval – dolomite crystal aggregate or grainstone/packstone fabric.	X	X
18	Gulf-Aztec-Lockhart-Fed 1	SWSW 22 28S 20E	San Juan	4770–75	8	1.4–1.6	1.5	cuttings	A interval – dolomite and dolomitic shale.		
18	Gulf-Aztec-Lockhart-Fed 1	SWSW 22 28S 20E	San Juan	4775–80	10	0.8–1.5	1.1	cuttings	B interval – micro rhombic dolomite; possible ooids or peloids.		
18	Gulf-Aztec-Lockhart-Fed 1	SWSW 22 28S 20E	San Juan	4780–85	10	0.6–2.2	1.8	cuttings	B interval – crystalline dolomite to skeletal grainstone fabric showing good epifluorescence and microcrystalline dolomite aggregates; some anhydrite lathes and rhombic dolomite.	X	X
18	Gulf-Aztec-Lockhart-Fed 1	SWSW 22 28S 20E	San Juan	4785–90	10	1.2–2.8	2	cuttings	B interval – anhydritic dolomite showing live oil films; anhydrite lathes, organic (microbial?) structures, and bitumen present.	X	X

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
18	Gulf-Aztec-Lockhart-Fed 1	SWSW 22 28S 20E	San Juan	4790–95	9	0.8–2.2	1.6	cuttings	C interval – dolomitic shale.		
18	Gulf-Aztec-Lockhart-Fed 1	SWSW 22 28S 20E	San Juan	4795–4800	10	1.7–2.2	1.9	cuttings	C interval – silty and dolomitic shale.		
18	Gulf-Aztec-Lockhart-Fed 1	SWSW 22 28S 20E	San Juan	4800–10	10	1.6–2.5	2	cuttings	C interval – completely oil saturated dolomite to silty dolomite, crystalline dolomite and dolomitic aggregates, and some possible laminations; bitumen present.	X (see figure 11E)	X
18	Gulf-Aztec-Lockhart-Fed 1	SWSW 22 28S 20E	San Juan	4810–15	9	1.5–2.4	1.9	cuttings	C interval – silty dolomites.		
18	Gulf-Aztec-Lockhart-Fed 1	SWSW 22 28S 20E	San Juan	4815–20	10	1.8–3.0	2.2	cuttings	C interval – fractured dolomite showing live oil films; anhydritic dolomite and rhombic crystalline dolomite.	X	X
19	USA Lockhart 1	SESE 23 28S 20E	San Juan	4380–90	10	0.3–1.0	0.6	cuttings	B interval – slightly dolomitic shale; medium size cuttings.		
19	USA Lockhart 1	SESE 23 28S 20E	San Juan	4390–4400	7	0.4–1.0	0.7	cuttings	B interval – dolomitized shale; large size cuttings.		
19	USA Lockhart 1	SESE 23 28S 20E	San Juan	4400–10	10	0.7–1.1	0.9	cuttings	C interval – slightly to highly dolomitic shale; medium-large cuttings.		
19	USA Lockhart 1	SESE 23 28S 20E	San Juan	4410–20	9	0.9–1.3	1.1	cuttings	C interval –dolomitic shale; medium-large cuttings.		
19	USA Lockhart 1	SESE 23 28S 20E	San Juan	4420–30	10	0.7–1.2	0.9	cuttings	C interval – slightly to moderate dolomitic shale; medium-large cuttings.		
20	Government B-1	NENE 34 28S 22E	San Juan	7535–45	9	1.4–2.1	1.7	cuttings	A interval – medium crystalline dolomite, silty, wackestone/packstone fabric, and highly variable fluorescent.		
20	Government B-1	NENE 34 28S 22E	San Juan	7545–55					No samples		
20	Government B-1	NENE 34 28S 22E	San Juan	7555–65	9	0.6–1.8	1.3	cuttings	A interval – fine to medium crystalline dolomite, occasionally silty, mudstone/wackestone fabric containing patches of argillaceous matrix; no visible porosity.		
20	Government B-1	NENE 34 28S 22E	San Juan	7565–75	10	0.5–3.2	1.6	cuttings	A interval – fine to medium crystalline dolomite, silty, and mudstone/wackestone fabric showing variable dim to bright fluorescence.	X	X
20	Government B-1	NENE 34 28S 22E	San Juan	7575–85	10	0.5–3.1	1.2	cuttings	A interval – finely crystalline dolomite containing silty and argillaceous mixtures; highly variable fluorescence and no visible porosity.	X	X
20	Government B-1	NENE 34 28S 22E	San Juan	7585–95	10	0.7–2.1	1.4	cuttings	A interval – fine to medium crystalline dolomite consisting of a silty and argillaceous matrix; mudstone/wackestone fabric, no visible porosity, and generally dim fluorescence.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
		Section, Township, Range				Range	Ave.				
20	Government B-1	NENE 34 28S 22E	San Juan	7595–7600	10	0.5–2.5	1	cuttings	B interval – fine to medium crystalline dolomite consisting of a silty and argillaceous matrix; mudstone/wackestone fabric, no visible porosity, and generally dim fluorescence.		
20	Government B-1	NENE 34 28S 22E	San Juan	7600–10	10	0.6–1.9	1.4	cuttings	B interval – medium crystalline dolomite, mudstone/wackestone fabric showing argillaceous patches, no visible porosity, and generally dim fluorescence.		
20	Government B-1	NENE 34 28S 22E	San Juan	7610–20	9	0.8–3.0	1.7	cuttings	B interval – fine to medium crystalline dolomite, wackestone/packstone fabric, occasionally silty and argillaceous showing no visible porosity and highly variable fluorescence.	X	X
20	Government B-1	NENE 34 28S 22E	San Juan	7620–30	10	0.5–2.1	1.4	cuttings	B interval – silty dolomite, fine to medium crystalline, mudstone/wackestone fabric showing no visible porosity and variable fluorescence.		
20	Government B-1	NENE 34 28S 22E	San Juan	7630–40	7	0.8–1.9	1.3	cuttings	B interval – medium crystalline dolomite showing a patchy argillaceous matrix, slightly silty, mudstone/wackestone fabric, no visible porosity, and generally dim fluorescence.		
20	Government B-1	NENE 34 28S 22E	San Juan	7640–50	9	0.9–2.9	1.8	cuttings	B interval – fine to medium crystalline dolomite, occasional silty packstone/wackestone fabric showing argillaceous patches, no visible porosity, and highly variable fluorescence.	X	X
20	Government B-1	NENE 34 28S 22E	San Juan	7650–60	7	0.6–1.5	1	cuttings	B interval – fine to medium crystalline dolomite, mudstone/wackestone fabric having argillaceous patches, no visible porosity, and very dim fluorescence.		
20	Government B-1	NENE 34 28S 22E	San Juan	7660–70					No samples.		
20	Government B-1	NENE 34 28S 22E	San Juan	7670–80	9	0.5–2.7	1.6	cuttings	C interval – fine to medium crystalline dolomite, wackestone/packstone/grainstone fabric, occasional argillaceous patches, low to moderate visible porosity, and highly variable fluorescence.	X	X
20	Government B-1	NENE 34 28S 22E	San Juan	7680–90	8	1.3–2.0	1.8	cuttings	C interval – fine to medium crystalline dolomite, mudstone/wackestone fabric, very poor visible porosity, and highly variable fluorescence.		
20	Government B-1	NENE 34 28S 22E	San Juan	7690–7700	10	0.5–1.9	1.4	cuttings	C interval – fine to medium crystalline dolomite, mudstone/wackestone fabric, occasional argillaceous patches, no visible porosity, and generally dim fluorescence.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image† (see appendix C)
		Section, Township, Range				Range	Ave.				
20	Government B-1	NENE 34 28S 22E	San Juan	7700–10	9	1.2–1.7	1.5	cuttings	C interval – medium crystalline dolomite, wackestone/packstone fabric, occasional argillaceous patches, no visible porosity, and generally dim fluorescence.		
20	Government B-1	NENE 34 28S 22E	San Juan	7710–20	10	1.4–2.9	1.7	cuttings	C interval – fine to medium crystalline dolomite, wackestone/packstone/grainstone fabric, generally low visible porosity, some possible anhydrite and argillaceous patches, and highly variable fluorescence; bitumen present.	X	X
21	Horsehead Unit 1	NWSW 18 29S 21E	San Juan	6290–6300	10	0.7–1.5	1.3	cuttings	A interval – microcrystalline, argillaceous dolomite, disseminated sulfides, and dolomitic shale to silty dolomitic shale. Note: cutting are half shale and half halite.	X (see figures 11A and 11B)	X (see figure 19B)
21	Horsehead Unit 1	NWSW 18 29S 21E	San Juan	6300–10	10	1.3–1.7	1.5	cuttings	A interval – mostly black to dark gray shale and minor amount of dark brown microcrystalline dolomite; dolomitic shale, slightly silty.	X	X
21	Horsehead Unit 1	NWSW 18 29S 21E	San Juan	6310–20	10	1.0–1.7	1.4	cuttings	B interval – mostly dark gray dolomitic shale to silt and minor amounts of dolomite.	X	X
21	Horsehead Unit 1	NWSW 18 29S 21E	San Juan	6320–30	10	1.4–2.2	1.8	cuttings	B interval – microcrystalline dolomite showing microporosity and probable oil saturation; saline minerals (anhydrite or halite) also present.	X	X
21	Horsehead Unit 1	NWSW 18 29S 21E	San Juan	6330–40	10	1.8–3.0	2.2	cuttings	B interval – dolomitic shale containing significant halite and/or anhydrite; 50% microcrystalline dolomite either highly organic or oil saturated, 50% slightly dolomitic shale.	X	X
21	Horsehead Unit 1	NWSW 18 29S 21E	San Juan	6340–50	10	1.5–2.5	1.9	cuttings	B interval – mostly highly organic black to dark gray, highly dolomitic shale showing small nodes of incipient dolomite formation; minor evaporites.	X	X
21	Horsehead Unit 1	NWSW 18 29S 21E	San Juan	6350–60	10	1.8–2.2	2	cuttings	C interval – peloidal black organic shale (non-laminated) and dolomitic shale.		X (see figure 19C)
21	Horsehead Unit 1	NWSW 18 29S 21E	San Juan	6360–70	10	1.3–2.0	1.6	cuttings	C interval – peloidal, partially dolomitized organic shale and slightly dolomitic shale.	X	X (see figure 19D)
21	Horsehead Unit 1	NWSW 18 29S 21E	San Juan	6370–80	10	1.1–2.3	1.7	cuttings	C interval – dark gray to black peloidal shale and dolomitic shale; partially dolomitized and medium to dark brown peloidal dolomite.	X	X
21	Horsehead Unit 1	NWSW 18 29S 21E	San Juan	6380–90	10	1.1–2.1	1.7	cuttings	C interval – mostly non-laminated peloidal organic shale, black to dark gray and much less brown dolomite; some shale and dolomitic shale. White dolomite-filled microfractures contain abundant sulfide minerals in fractures fill.	X	X

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
22	Hatch Point 1	NESE 14 29S 21E	San Juan	7220–30	10	1.2–2.2	1.6	cuttings	B interval – dolomitic shale and rhombic dolomite clasts within black shale; bitumen present in intercrystalline pores (all halite from 7230–7240').	X	X
22	Hatch Point 1	NESE 14 29S 21E	San Juan	7240–50	10	0.0–1.5	0.7	cuttings	B interval – mostly black shale, no epifluorescence.		
22	Hatch Point 1	NESE 14 29S 21E	San Juan	7250–60	10	0.3–2.2	1.1	cuttings	C interval – silty and slightly dolomitic shale.		
22	Hatch Point 1	NESE 14 29S 21E	San Juan	7260–70	8	1.2–2.4	1.9	cuttings	C interval – dolomitic shale, anhydritic dolomite, and dolomite aggregates within shale; bitumen present.	X (see figure 11D)	X
23	Threemile 12-7	NWSE 12 29S 21E	San Juan	7530–60	8	1.5–2.3	1.9	cuttings	Horizontal well – dolomitic shale, dolomite, and silty shale(?) (all halite from 7560–7650').		
23	Threemile 12-7	NWSE 12 29S 21E	San Juan	7650–70	10	1.0–2.5	1.9	cuttings	Horizontal well – dolomitic shale and anhydritic dolomite.	X	X
23	Threemile 12-7	NWSE 12 29S 21E	San Juan	7670–78	10	1.0–2.2	1.6	cuttings	Horizontal well – silty slightly dolomitic shale.		
23	Threemile 12-7	NWSE 12 29S 21E	San Juan	7678–90	10	0.3–1.5	0.8	cuttings	Horizontal well – silty shale.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7580–90	10	0.3–1.5	0.7	cuttings	A interval –black organic shale, occasional patches of finely crystalline dolomite, and no visible porosity.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7590–7600	9	0.3–1.7	0.7	cuttings	A interval – black organic shale, occasional patches of finely crystalline dolomite consisting of greater amounts of microcrystalline dolomite showing no visible porosity and very dim fluorescence.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7600–10	9	0.3–1.5	0.6	cuttings	B interval – organic-rich black shale showing very little dolomite or silt grains.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7610–20	9	0.3–1.3	0.5	cuttings	B interval – organic-rich black shale showing very little dolomite or silt grains.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7620–30	9	0.3–1.5	0.8	cuttings	B interval – silty dolomite, occasionally argillaceous, and showing visible intercrystalline pores.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7630–40	8	0.3–2.0	0.7	cuttings	C interval – black, argillaceous dolomite, traces of halite; possible microbialite fabric in finely crystalline dolomite.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7640–50	6	0.3–1.1	0.9	cuttings	C interval – black, argillaceous dolomite showing possible microbialite fabric in finely crystalline dolomite.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7650–60	10	0.5–1.7	0.9	cuttings	C interval – black, argillaceous dolomite (slightly more than the 7640–50' zone); possible microbialite fabric in finely crystalline dolomite.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7660–70	10	0.7–2.0	1.2	cuttings	C interval – highly dolomitic matrix with occasional argillaceous patches, fine to medium crystalline dolomite; possibly microbial showing some visible porosity.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7670–80	8	0.3–1.8	0.9	cuttings	C interval – black, organic shale interbedded with slightly argillaceous dolomite and fine to medium crystalline dolomite; mudstone/wackestone fabric.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7680–90	10	0.5–2.0	1.1	cuttings	C interval – fine to medium crystalline dolomite showing some possible tubular microbial structures and patches of argillaceous and/or organic matrix.		
24	La Sal USA 1	NWNE 19 29S 24E	San Juan	7690–7700	8	0.3–1.7	0.8	cuttings	C interval – black organic-rich shale, minor small patches of finely crystalline dolomite, and no visible porosity.		
25	Lisbon D232	NENE 32 29.5S 24E	San Juan	7770–7820	10	0	0	cuttings	Interval tops not available – large fresh samples dominated by sections of black shale.		
25	Lisbon D232	NENE 32 29.5S 24E	San Juan	7820–30	10	0–0.6	0.4	cuttings	Interval tops not available – silty shale.		
25	Lisbon D232	NENE 32 29.5S 24E	San Juan	7830–40	10	0–0.4	0.1	cuttings	Interval tops not available – silty shale.		
25	Lisbon D232	NENE 32 29.5S 24E	San Juan	7840–50	10	0.2–0.7	0.5	cuttings	Interval tops not available – silty shale.		
25	Lisbon D232	NENE 32 29.5S 24E	San Juan	7850–60	10	0.0–0.5	0.2	cuttings	Interval tops not available – silty and dolomitic shale.		
25	Lisbon D232	NENE 32 29.5S 24E	San Juan	7860–70	10	0.1–0.4	0.2	cuttings	Interval tops not available – dolomitic shale.		
26	Gibson Dome	21 30S 21E	San Juan	5220–30	10	0.7–2.1	1.6	core	A interval – dolomitic siltstone to silty dolomite showing fine to medium dolomite rhombs and some intercrystalline porosity; moderately good fluorescence.		
26	Gibson Dome	21 30S 21E	San Juan	5230–40	10	1.1–2.2	1.8	core	A interval – fine to medium crystalline or anhydritic dolomite showing patchy variable fluorescence; also organic slightly silty black shale.	X	X
26	Gibson Dome	21 30S 21E	San Juan	5240–50	10	1.3–2.1	1.9	core	A interval – siltstone with some intercrystalline porosity and occasional patches of finely crystalline dolomite.		
26	Gibson Dome	21 30S 21E	San Juan	5250–60	10	2.0–2.4	2.1	core	B interval – well sorted siltstone showing some intercrystalline porosity, occasional patches of medium crystalline to silty dolomite, and thin beds of silty shale.	X	X
26	Gibson Dome	21 30S 21E	San Juan	5260–70	9	2.0–2.3	2.1	core	B interval – dolomitic siltstone and purer siltstone showing variable amounts of visible pore space; fair to good fluorescence.	X	X

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
26	Gibson Dome	21 30S 21E	San Juan	5270–80	10	0.7–2.2	1.3	core	C interval – silty shale to argillaceous siltstone, with very low visible porosity, possible interbeds of pure siltstone with fair fluorescence.		
26	Gibson Dome	21 30S 21E	San Juan	5280–90	10	1.5–2.1	1.8	core	C interval, silty shale to argillaceous siltstone very low visible porosity, and possible interbeds of pure siltstone showing fair fluorescence.		
26	Gibson Dome	21 30S 21E	San Juan	5290–5300	10	0.5–2.2	1.8	core	C interval – well sorted siltstone and dolomitic siltstone as well as dolomite grainstone fabric; fair to good visible intercrystalline porosity.	X	X
26	Gibson Dome	21 30S 21E	San Juan	5300–10	10	1.0–2.1	1.8	core	C interval – dolomitic siltstone and pure siltstone showing variable visible intercrystalline porosity; some possible microbial dolomite.	X	X
27	Little Valley 2	SESE 29 30S 25E	San Juan	8370–80	5	0.3–0.5	0.3	cuttings	A interval – soft organic black shale and very minor patches of finely crystalline dolomite; note strong sampling bias to black shale.		
27	Little Valley 2	SESE 29 30S 25E	San Juan	8380–90	10	0.3–0.6	0.4	cuttings	A interval – soft organic black shale containing very minor patches of finely crystalline dolomite; note strong sampling bias to black shale.		
27	Little Valley 2	SESE 29 30S 25E	San Juan	8390–8400	10	0.3–0.8	0.4	cuttings	B interval – black organic shale and larger isolated patches of fine to medium crystalline dolomite.		
27	Little Valley 2	SESE 29 30S 25E	San Juan	8400–10	10	0.3–1.2	0.6	cuttings	B interval – good sample of fine to medium crystalline dolomite showing intercrystalline porosity and possible microbial fabric; variable amounts of organic black argillaceous matrix.		
28	Hart Point Unit #1	SENW 8 31S 22E	San Juan	6740–50	8	0.7–2.1	1.4	cuttings	A interval – black silty organic-rich shale, very little to no dolomite; patchy fluorescence.		
28	Hart Point Unit #1	SENW 8 31S 22E	San Juan	6750–60	10	0.5–2.0	1.4	cuttings	A interval – black dolomitic and silty shale, small clusters of finely crystalline dolomite, and anhydrite patchy fluorescence.		
28	Hart Point Unit #1	SENW 8 31S 22E	San Juan	6760–70	10	0.7–1.8	1.2	cuttings	B interval – black dolomitic and silty shale, small clusters of finely crystalline dolomite, and anhydrite patchy fluorescence; slightly more silty than 6750–60'.		
28	Hart Point Unit #1	SENW 8 31S 22E	San Juan	6770–80	9	0.8–2.5	1.9	cuttings	B interval – fine to medium crystalline dolomite and siltstone, some visible pore space; possible microbial structure in the dolomite.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
28	Hart Point Unit #1	SENW 8 31S 22E	San Juan	6780–90	10	1.7–2.5	2.1	cuttings	B interval – patches of fine to medium crystalline dolomite surrounded by silty argillaceous matrix and visible intercrystalline pores within dolomite patches; bitumen present.	X	X
28	Hart Point Unit #1	SENW 8 31S 22E	San Juan	6790–6800					No cuttings.		
28	Hart Point Unit #1	SENW 8 31S 22E	San Juan	6800–10	10	0.8–2.1	1.5	cuttings	C interval – argillaceous siltstone showing possible anhydrite patches.		
28	Hart Point Unit #1	SENW 8 31S 22E	San Juan	6810–20	10	0.7–2.3	1.6	cuttings	C interval – argillaceous siltstone and clusters of fine to medium crystalline dolomite, and anhydritic; highly variable and patchy fluorescence.	X	X
28	Hart Point Unit #1	SENW 8 31S 22E	San Juan	6820–30	10	0.7–2.3	1.5	cuttings	C interval – fine to medium crystalline dolomite showing microbial tubular structures interbedded with silty shale.		
29	Winchester 21-1H	NWNW 21 31S 24E	San Juan	7750–60	10	0.4–1.5	0.9	cuttings	Horizontal well – silty black shale and slightly dolomitic shale.		
29	Winchester 21-1H	NWNW 21 31S 24E	San Juan	7760–70	10	0.5–1.3	1	cuttings	Horizontal well – fine to medium crystalline dolomite mudstone and black shale containing dolomite crystal clusters.		
29	Winchester 21-1H	NWNW 21 31S 24E	San Juan	7770–80	10	0.4–1.5	0.8	cuttings	Horizontal well – silty and finely crystalline shale plus argillaceous dolomite mudstone.		
29	Winchester 21-1H	NWNW 21 31S 24E	San Juan	7780–90	10	0.3–1.2	0.8	cuttings	Horizontal well – black shale, clusters of fine to medium crystalline dolomite, and argillaceous dolomitic mudstone.		
29	Winchester 21-1H	NWNW 21 31S 24E	San Juan	7790–7800	10	0.5–1.3	0.9	cuttings	Horizontal well – finely crystalline dolomitic siltstone and shale containing finely crystalline dolomite clusters.		
29	Winchester 21-1H	NWNW 21 31S 24E	San Juan	7800–10	10	0.5–1.8	1	cuttings	Horizontal well – finely crystalline dolomitic siltstone and shale containing finely crystalline dolomite clusters.		
29	Winchester 21-1H	NWNW 21 31S 24E	San Juan	7810–20	10	0.5–1.6	1.1	cuttings	Horizontal well – silty, slightly dolomitic shale.		
29	Winchester 21-1H	NWNW 21 31S 24E	San Juan	7820–30	10	0.9–2.0	1.3	cuttings	Horizontal well – silty, slightly dolomitic shale and finely crystalline dolomitic mudstone.		
29	Winchester 21-1H	NWNW 21 31S 24E	San Juan	7830–40	10	0.5–1.8	0.9	cuttings	Horizontal well – silty, slightly dolomitic shale and finely crystalline dolomitic mudstone.		
30	Church Rock Unit 1	SENW 26 31S 23E	San Juan	7460–70	10	0.1–1.0	0.6	cuttings	B interval – shale and slightly silty shale.		
30	Church Rock Unit 1	SENW 26 31S 23E	San Juan	7470–80	10	0.3–1.8	0.8	cuttings	B interval – silty shale with occasional traces of dolomite.		
30	Church Rock Unit 1	SENW 26 31S 23E	San Juan	7480–90	9	0.5–1.5	1.1	cuttings	C interval – dolomite, dolomitic shale, and silty dolomite.		

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
30	Church Rock Unit 1	SENW 26 31S 23E	San Juan	7490–7500	10	0.1–1.2	0.5	cuttings	C interval – slightly dolomitic shale.		
30	Church Rock Unit 1	SENW 26 31S 23E	San Juan	7500–10	9	0.3–0.8	0.5	cuttings	C interval – silty shale and dolomitic shale.		
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7589.3	6	0.3–0.5	0.3	core	A interval – organic black shale; no visible silt or dolomite.		
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7592.5	10	1.7–2.3	2	core	A interval – light colored siltstone, occasional dolomite crystals and cement, generally poorly sorted, and low visible porosity.		
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7595.5	7	1.0–1.6	1.2	core	A interval – argillaceous, poorly sorted siltstone showing low visible porosity and no evidence of dolomite.		
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7600	10	1.0–1.8	1.3	core	B interval – silty dolomite, wackestone/packstone fabric; very low visible porosity.		
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7602.1	10	0.5–1.9	1.4	core	B interval – silty dolomite, wackestone/packstone fabric; very low visible porosity.		
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7604.7	10	1.5–2.3	1.9	core	B interval – medium crystalline dolomite, slightly silty showing poor to fair visible porosity; wackestone/packstone fabric.		
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7607.7	10	1.8–2.1	2	core	B interval – silty dolomite showing fine to medium dolomite crystals, patchy visible porosity, and fluorescence; wackestone/packstone fabric.		
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7611.3	10	1.9–2.5	2.2	core	B interval – slightly silty medium crystalline dolomite, packstone/grainstone and possible microbial fabrics; fairly good visible intercrystalline pores.	X	X
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7615.8	10	2.0–2.6	2.2	core	B interval – medium crystalline to silty dolomite, packstone/grainstone fabric showing good visible intercrystalline and interparticle porosity.	X	X
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7617.2	10	1.8–2.2	2	core	B interval – dolomitic siltstone, moderately well sorted showing patches of intercrystalline porosity and fluorescence.		
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7619.3	10	2.0–2.3	2.2	core	B interval – medium crystalline dolomite, packstone/grainstone fabric containing very minor silt; good visible intercrystalline porosity.	X	X
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7623.1	10	2.0–2.8	2.3	core	B interval – moderately well sorted siltstone, slightly dolomitic showing good visible intercrystalline porosity and fluorescence.	X	X

Well #	Well Name	Location	County	Interval (ft)	N	Rating*		Sample Type	Comments**	Epifluorescence Photomicrograph Image (see appendix C)	Binocular or Digital Microscope Image[†] (see appendix C)
		Section, Township, Range				Range	Ave.				
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7632.5	10	1.3–2.0	1.9	core	C interval – silty dolomite showing very low visible porosity and dim fluorescence; generally finely crystalline dolomite and silty wackestone/mudstone fabric.		
31	Cisco State 36-13	NWNE 36 31S 24E	San Juan	7648.8	10	0.1–0.9	0.4	core	C interval – black organic shale containing occasional isolated silt grains.		

*Notes:

- See figure 10 for well number location.
- Samples evaluated at 100X.
- Yellow highlighted epifluorescence rating represents the highest maximum value for the well.

N = number of samples

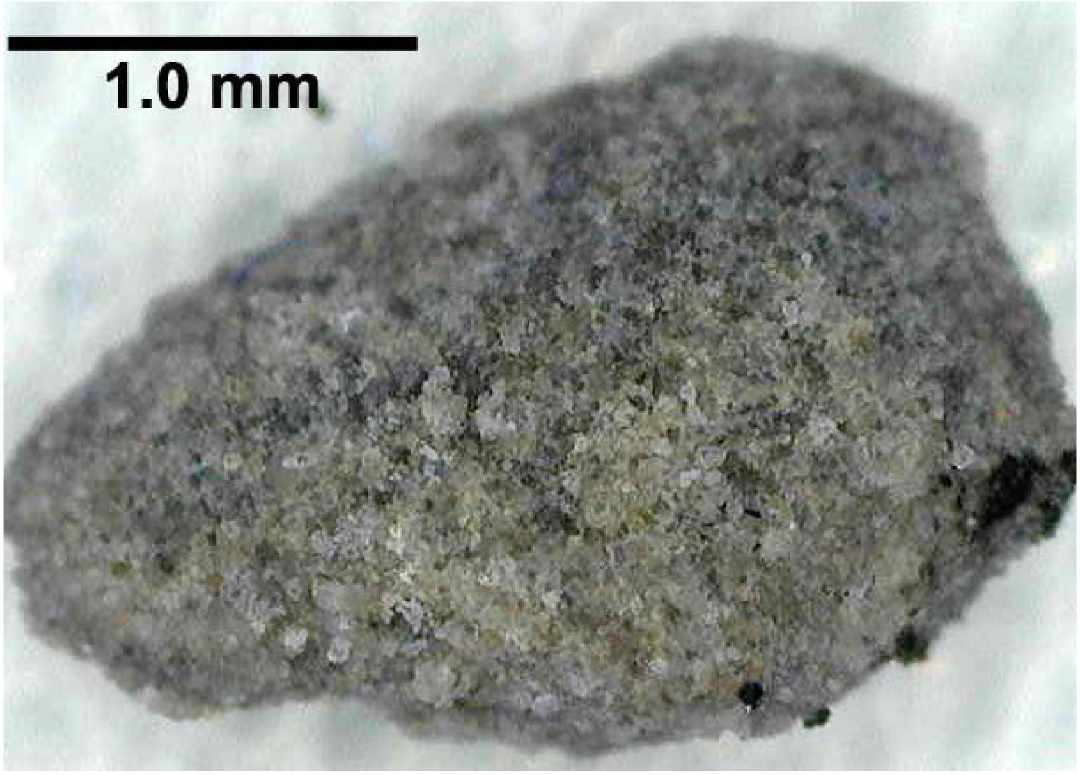
**Horizontal well – no Cane Creek shale intervals could be determined.

[†]Core samples are shown by high-resolution, close-up photographs of slabbed cores.

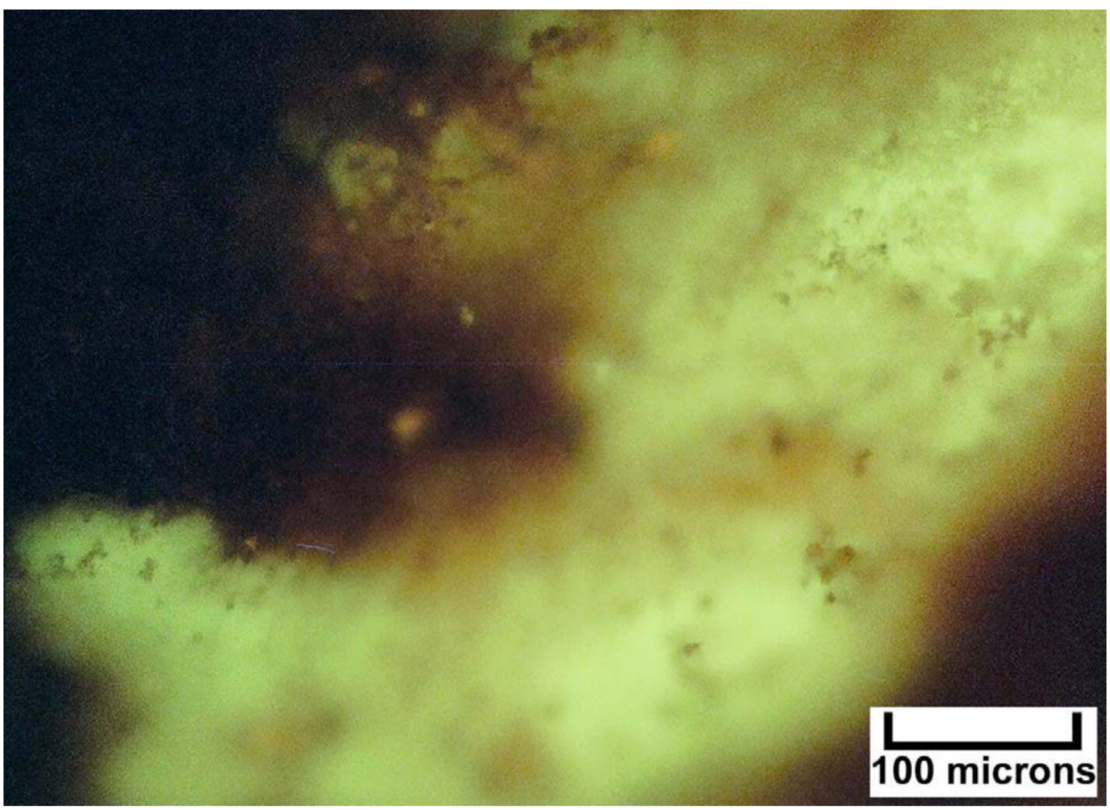
APPENDIX C

EPIFLUORESCENCE PHOTOMICROGRAPHS AND BINOCULAR/DIGITAL MICROSCOPE IMAGES

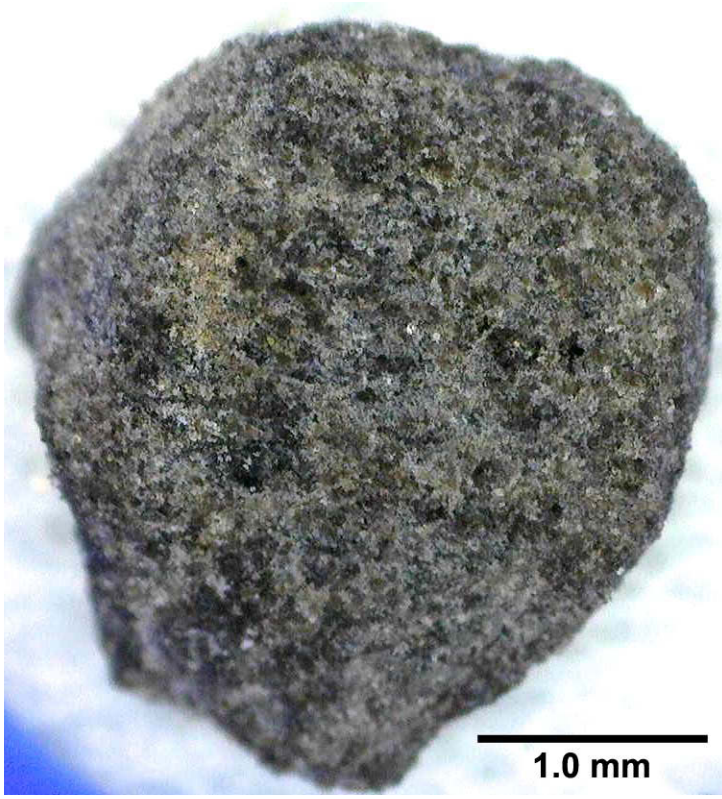
Note: Figure 10 shows the well number locations. Also, the quality of the cuttings images is variable. Most images were taken with a binocular microscope and are usually good quality, whereas some of the images taken with a digital microscope system resulted in quality that tended to be mixed. The poor-quality images of slabbed core from the Gibson Dome #1 well were the only ones available from the Texas Bureau of Economic Geology where the core is stored.



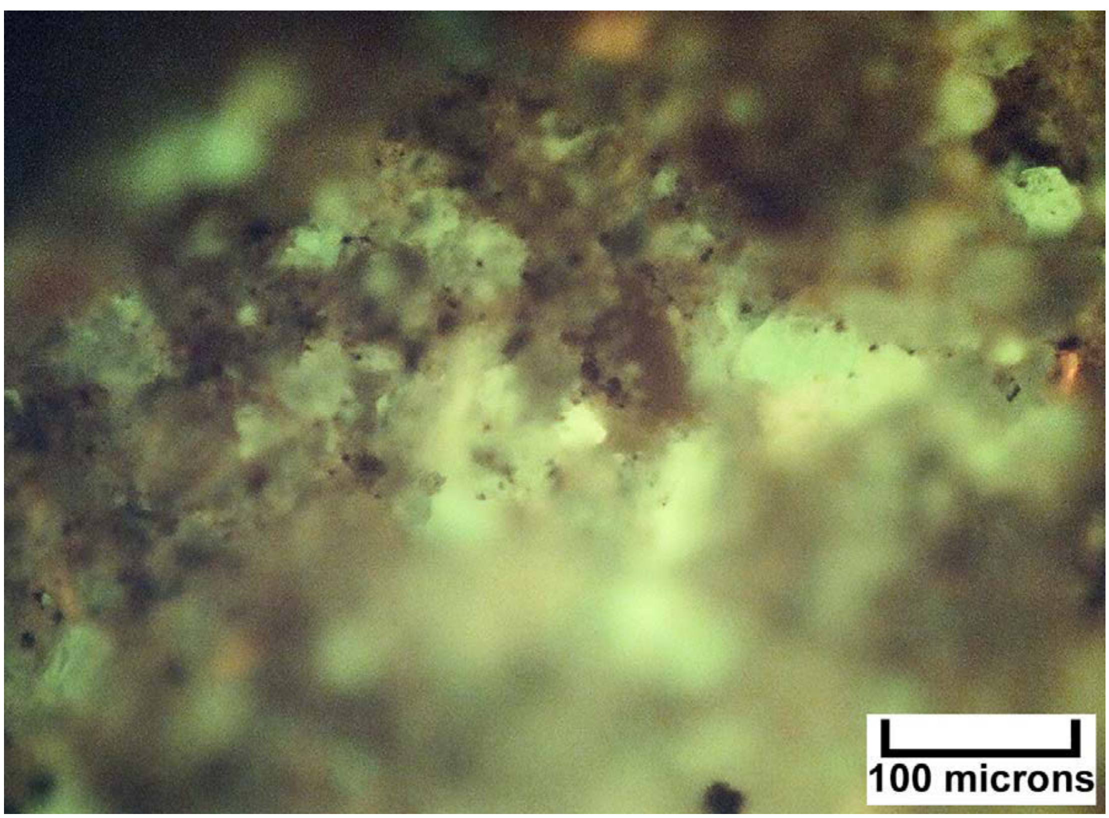
Digital microscope image (dry) – Jakey's Ridge #12-3 (Map #2), 8030-40 feet, B interval, dolomite, medium crystalline with patchy intercrystalline porosity and black particulate organic matter and micro-pyrite.



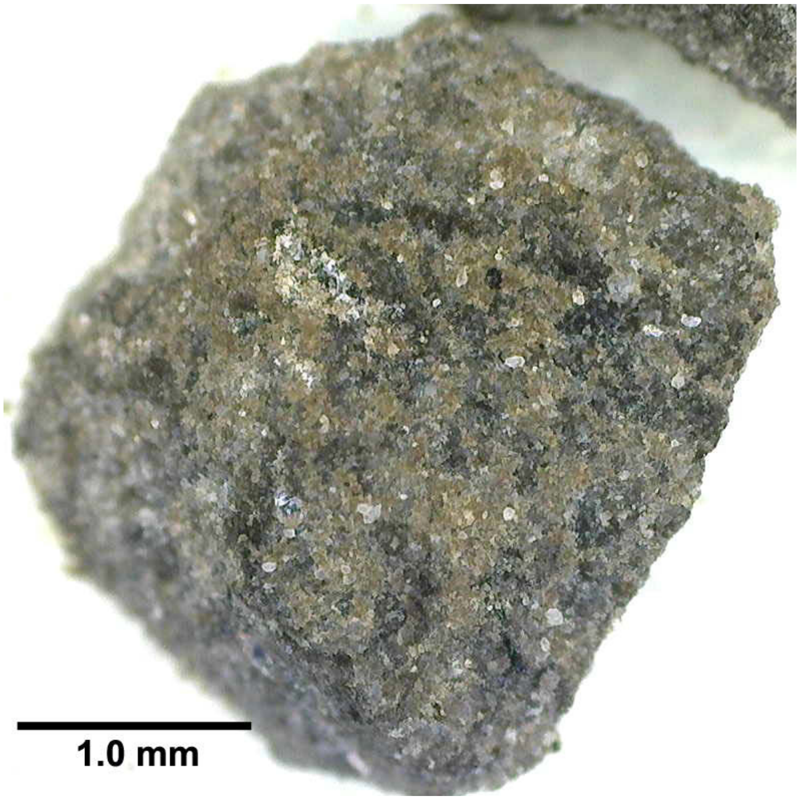
EF photomicrograph – Jakey's Ridge #12-3 (Map #2), 8030-40 feet, B interval, 2.4 visual epifluorescence rating in grain moldic dolomite.



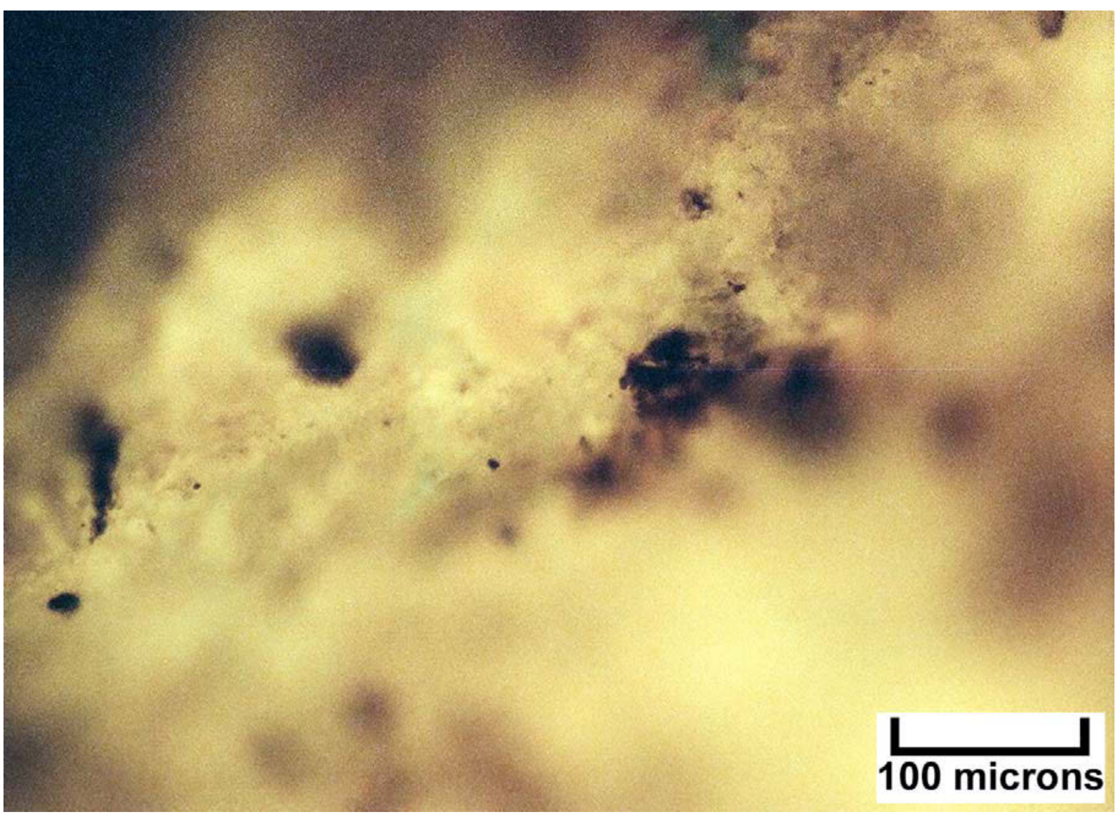
Digital microscope image (dry) – Jakey's Ridge #12-3 (Map #2), 8040-50 feet, B interval, medium to dark gray, organic-rich dolomite, fine to medium crystalline with patchy moldic and intercrystalline porosity. Possible bitumen within some pores.



EF photomicrograph – Jakey's Ridge #12-3 (Map #2), 8040-50 feet, B interval, 2.2 visual epifluorescence rating in dolomitic skeletal wackestone/packstone with possible bitumen lining pores.

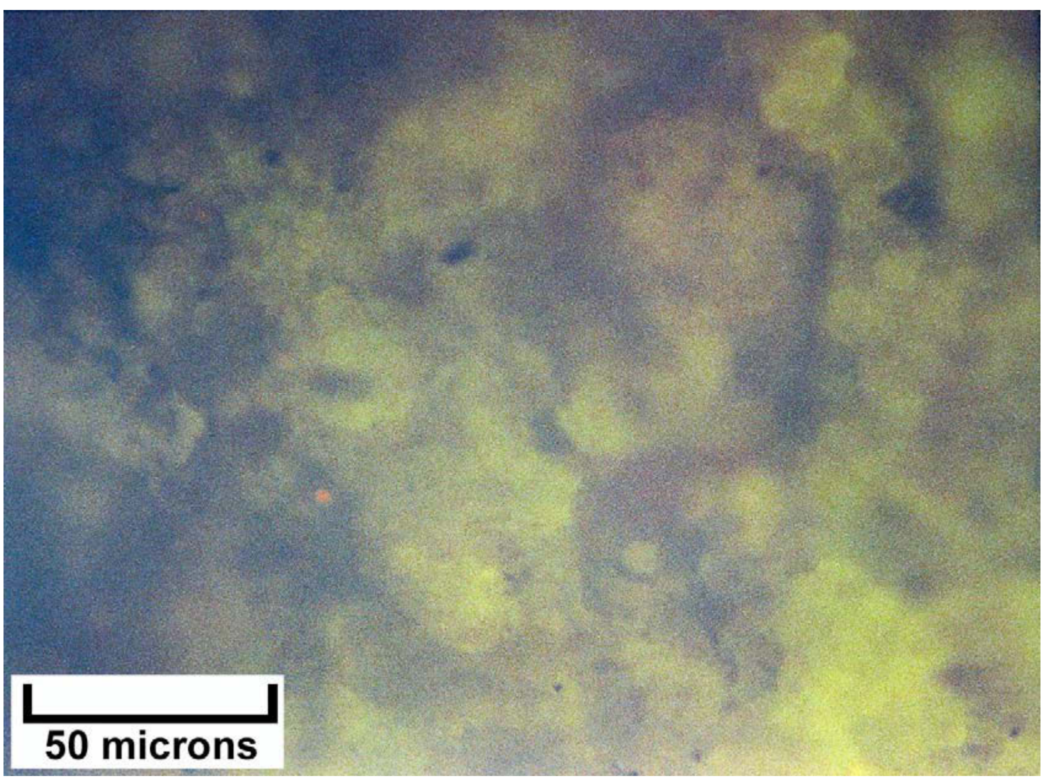


Digital microscope image (dry) – Jakey's Ridge #12-3 (Map #2), 8050-60 feet, B interval, medium to dark gray, medium crystalline dolomite, slightly silty with large patches of brownish oil staining around intercrystalline pore space.



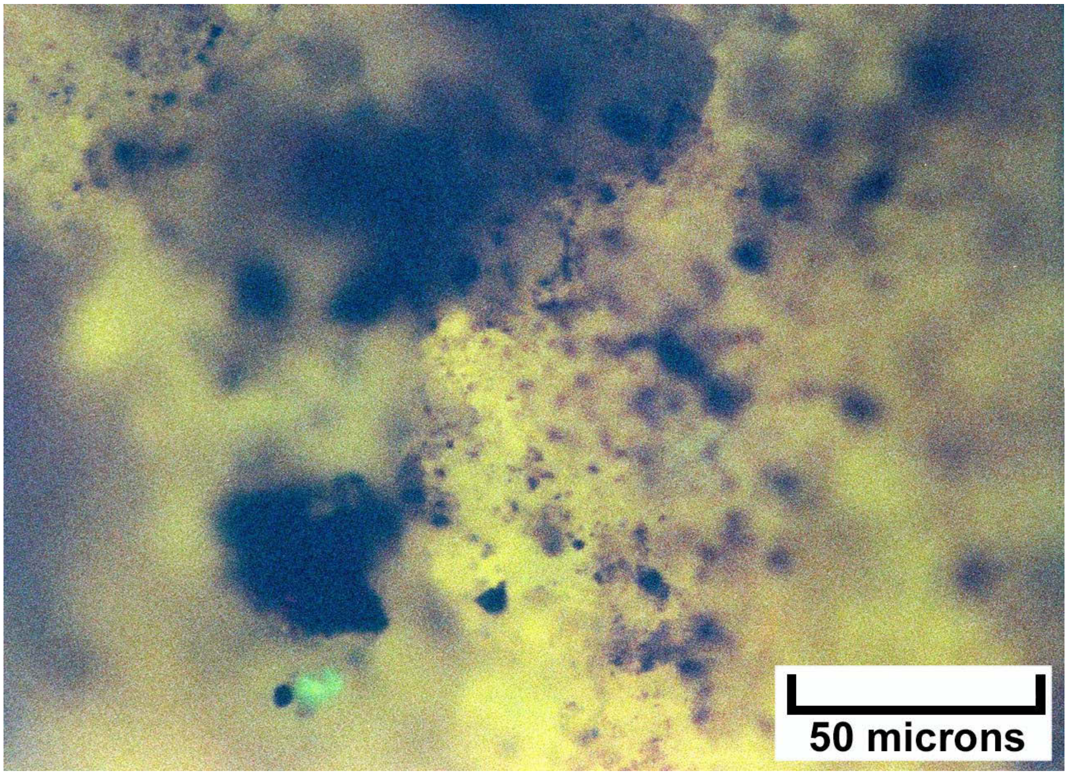
EF photomicrograph – Jakey's Ridge #12-3 (Map #2), 8050-60 feet, B interval, 2.4 visual epifluorescence rating in silty medium crystalline dolomitic wackestone/mudstone.

Digital microscope image (dry) – Jakey's Ridge #34-15 (Map #3), 7680-90 feet, B interval, two lithologies shown – left consists of slightly silty dolomitic black shale; right shows light gray, medium crystalline dolomite, possibly a grainstone/packstone.



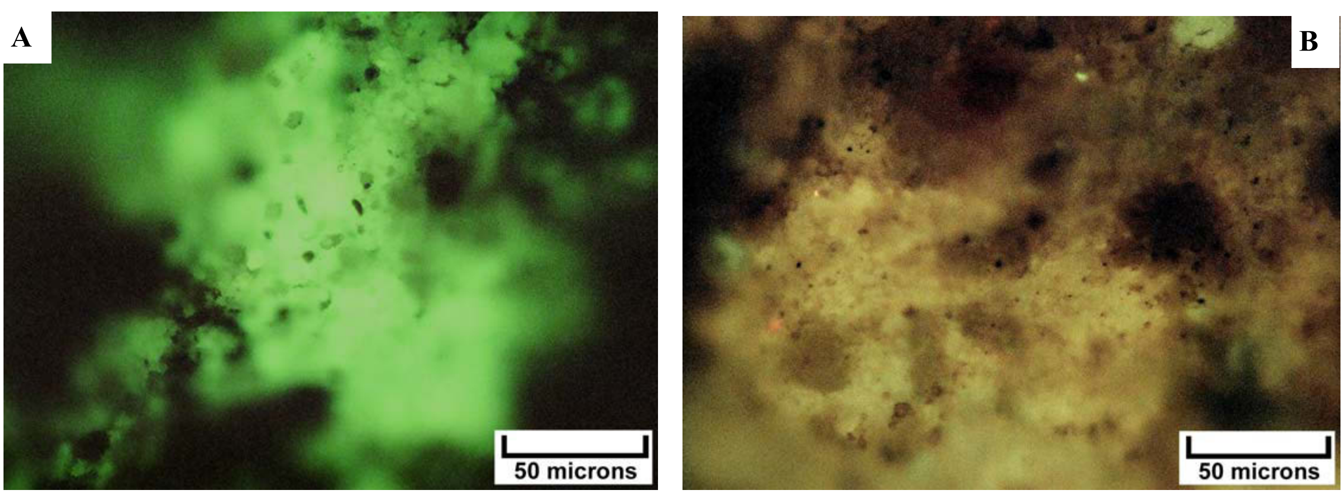
EF photomicrograph – Jakey's Ridge #34-15 (Map #3), 7680-90 feet, B interval, 2.1 visual epifluorescence rating in fine to medium crystalline dolomitic grainstone composed of micropeloids or coated grains, moderately bright fluorescence.

Digital microscope image (wet) – Jakey's Ridge #34-15 (Map #3), 7690-7700 feet, B interval, light gray to white, medium crystalline dolomite, grainstone/packstone with black argillaceous patches.

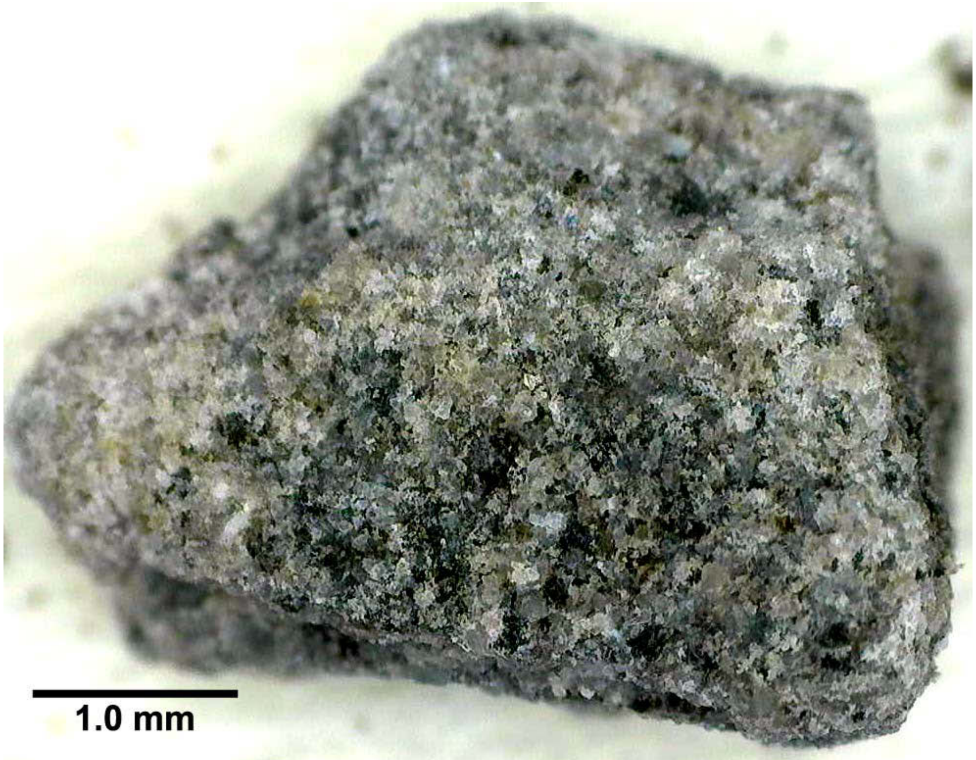


EF photomicrograph – Jakey's Ridge #34-15 (Map #3), 7690-7700 feet, B interval, 2.1 visual epifluorescence rating in finely crystalline dolomite, grainstone/packstone with small visible interparticle pores and moderate fluorescence.

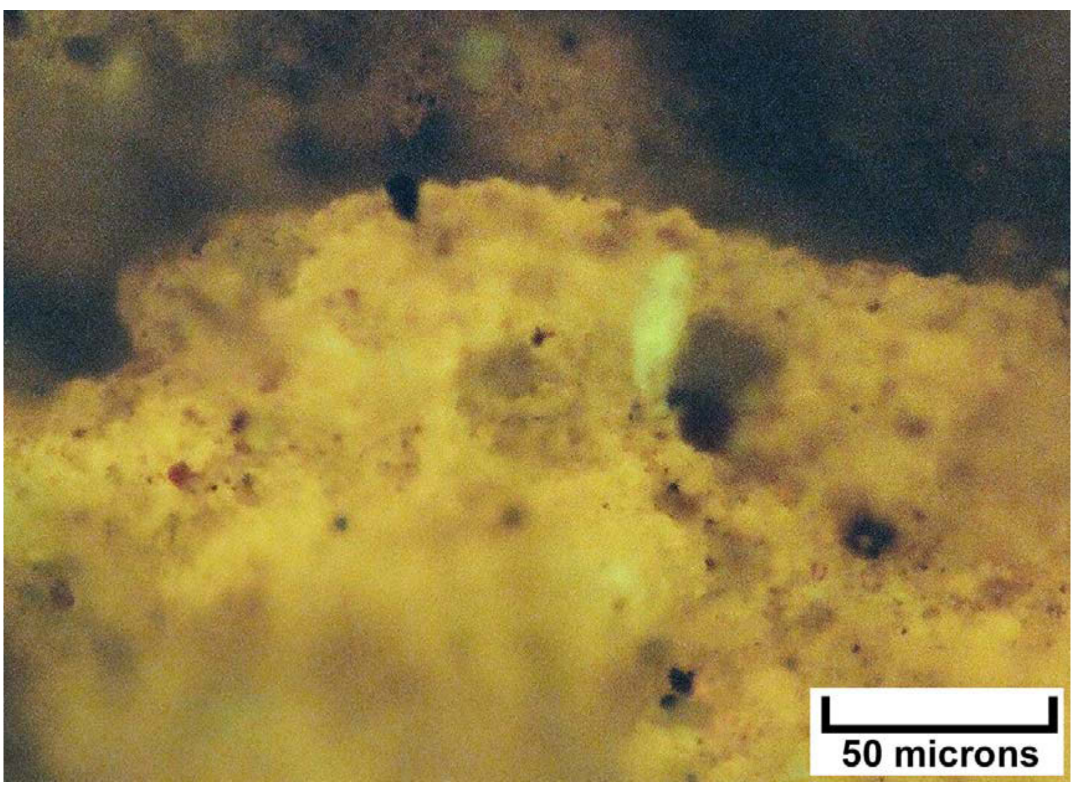
Digital microscope image (dry) – Salt Wash #1-16 (Map #4), 8250-60 feet (interval tops not available), light to medium gray, medium crystalline dolomite, grainstone/packstone with moderate intercrystalline pore space and patches of white anhydrite.



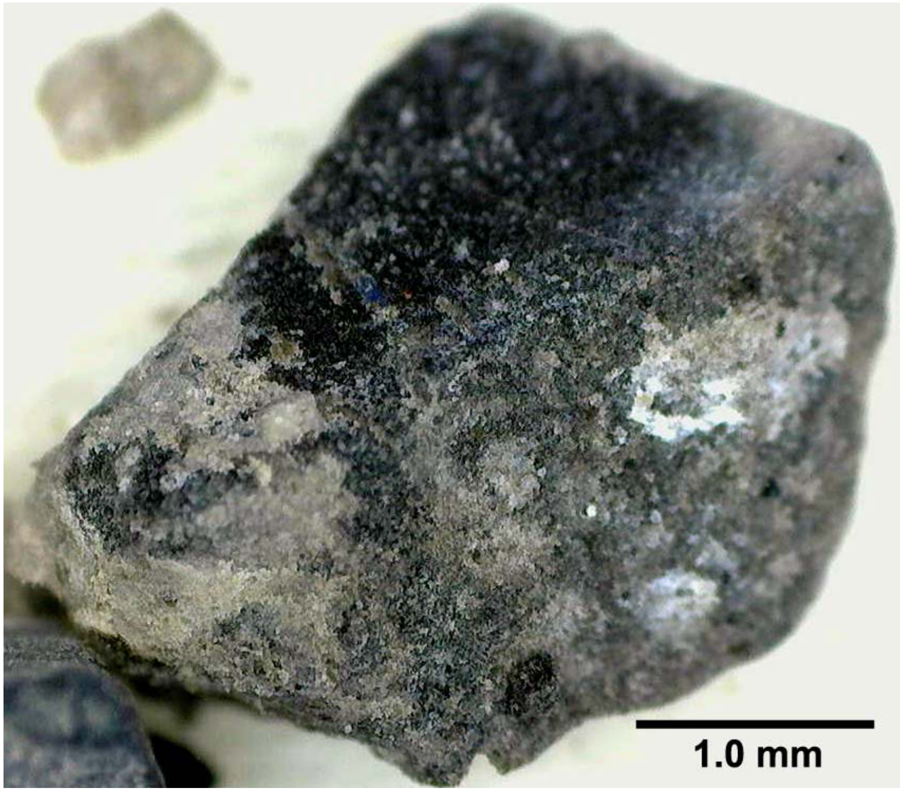
EF photomicrographs – Salt Wash #1-16 (Map #4), 8250-60 feet (interval tops not available). A: 3.0 visual epifluorescence rating in finely crystalline patchy dolomite within a black organic, non-fluorescing organic argillaceous matrix. B: 2.3 visual epifluorescence rating in fine to medium dolomite, porous tubular microbial fabric.



Digital microscope image (dry) – Salt Wash #1-16 (Map #4), 8260-70 feet (interval tops not available), medium to dark gray, medium crystalline dolomite, packstone/wackestone with some intercrystalline pore space.

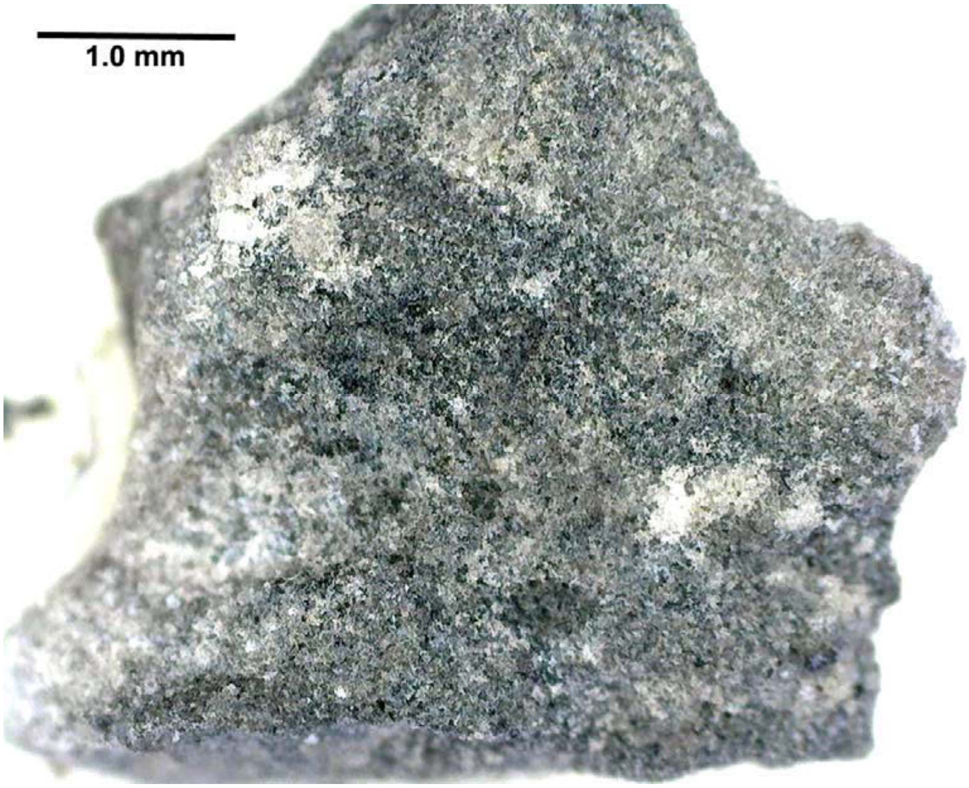


EF photomicrograph – Salt Wash #1-16 (Map #4), 8260-70 feet (interval tops not available), 2.6 visual epifluorescence rating in fine to medium crystalline dolomite, grainstone/ microbialite with good oil saturation.

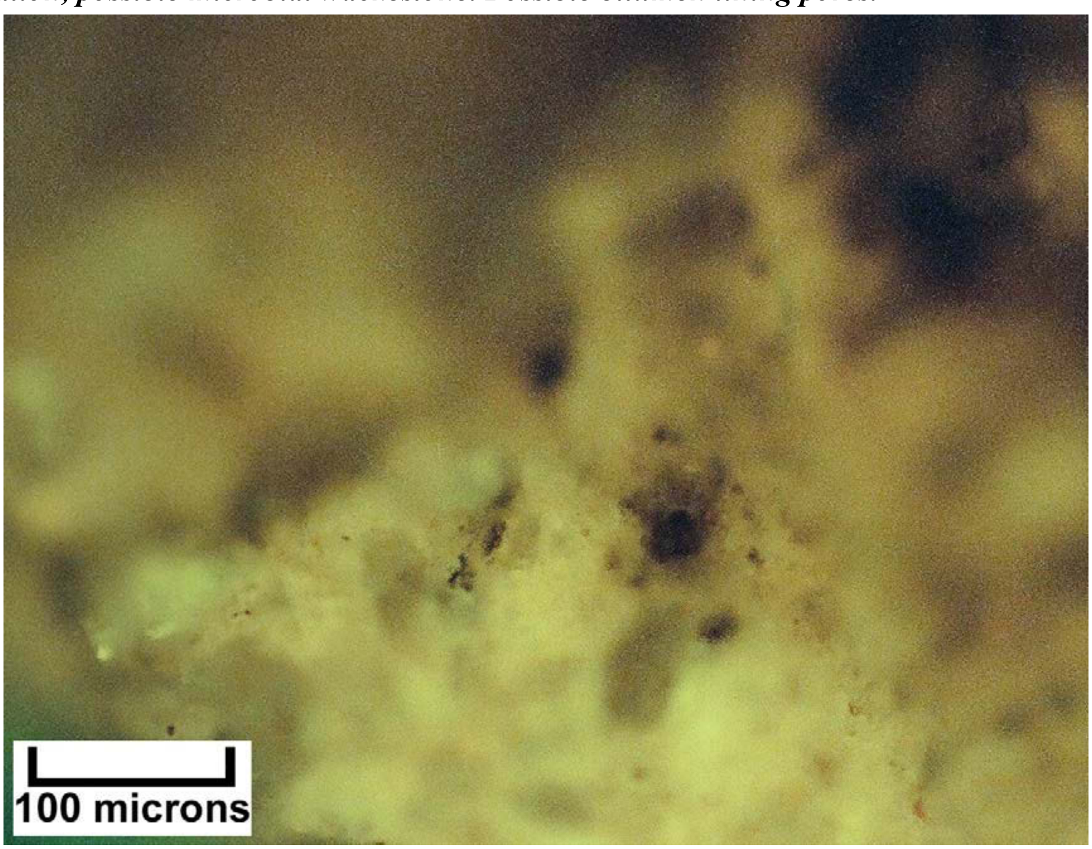


Digital microscope image (dry) – Salt Wash #1-16 (Map #4), 8270-80 feet (interval tops not available), medium to dark gray dolomite with pustular to lumpy microbial fabric, very limited visible intercrystalline porosity.

EF photomicrograph – Salt Wash #1-16 (Map #4), 8270-80 feet (interval tops not available), visual epifluorescence rating 2.9 in very fluorescent dolomite with microbialite texture.

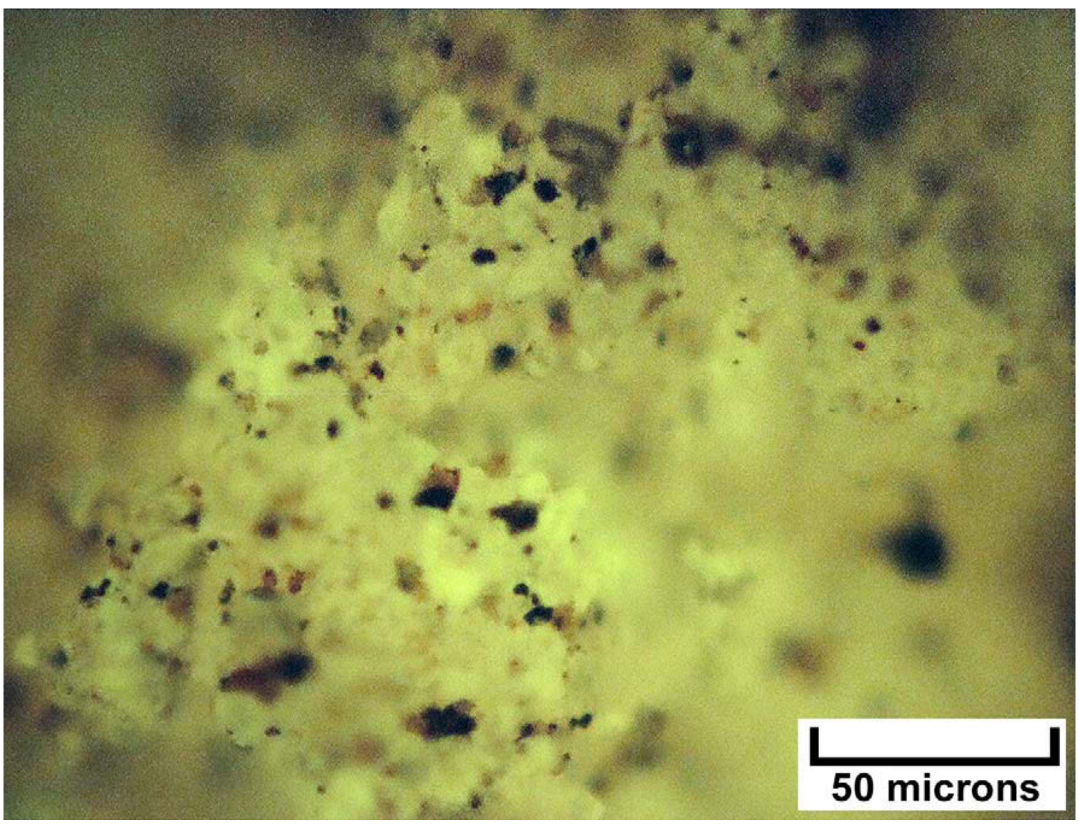


Digital microscope image (dry) – Salt Wash #1-16 (Map #4), 8280-90 feet (interval tops not available), medium to dark gray, fine to medium crystalline dolomite with wavy to horizontal lamination, possible microbial wackestone. Possible bitumen lining pores.



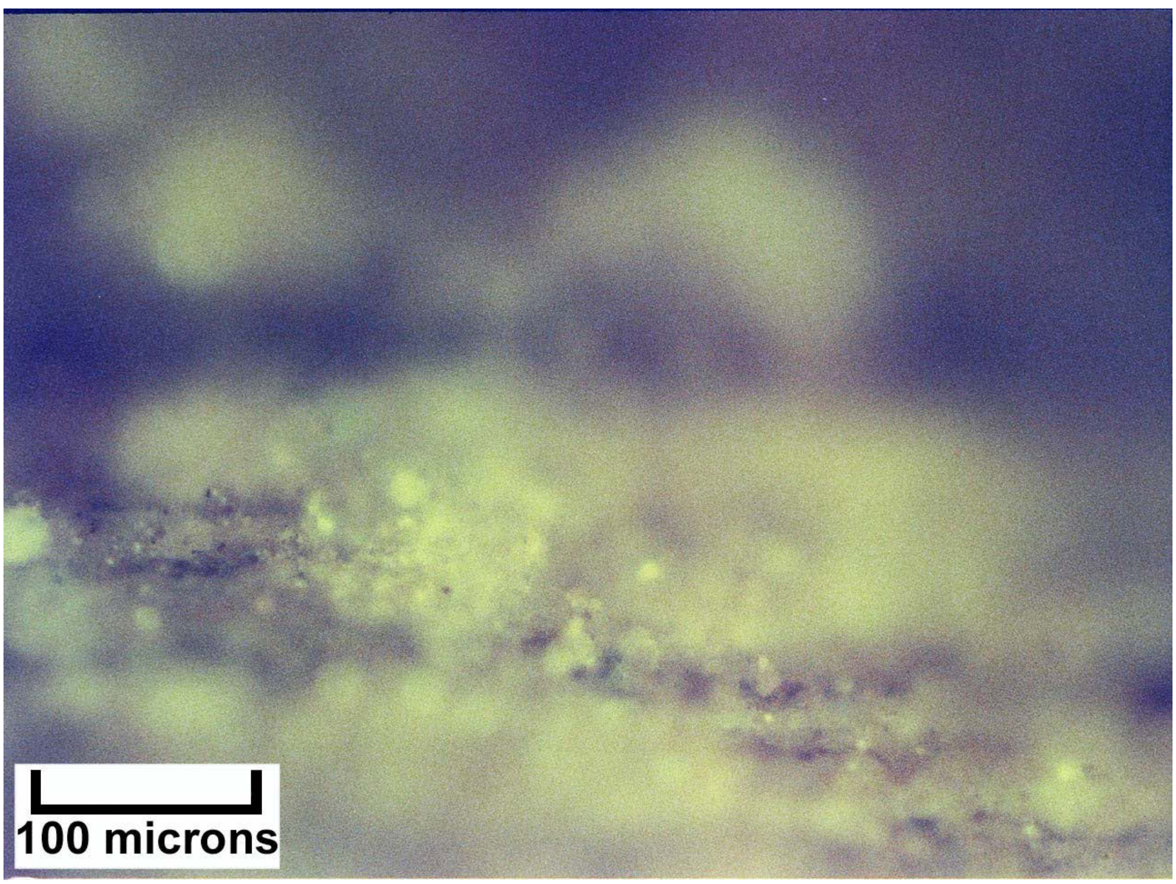
EF photomicrograph – Salt Wash #1-16 (Map #4), 8280-90 feet (interval tops not available), 2.8 visual epifluorescence rating in dolomitic tubular microbial fabric with visible porosity.

Digital microscope image (dry) – Salt Wash #1-16 (Map #4), 8320-30 feet (interval tops not available), light gray to gold, silty dolomite with apparent heavy oil staining.

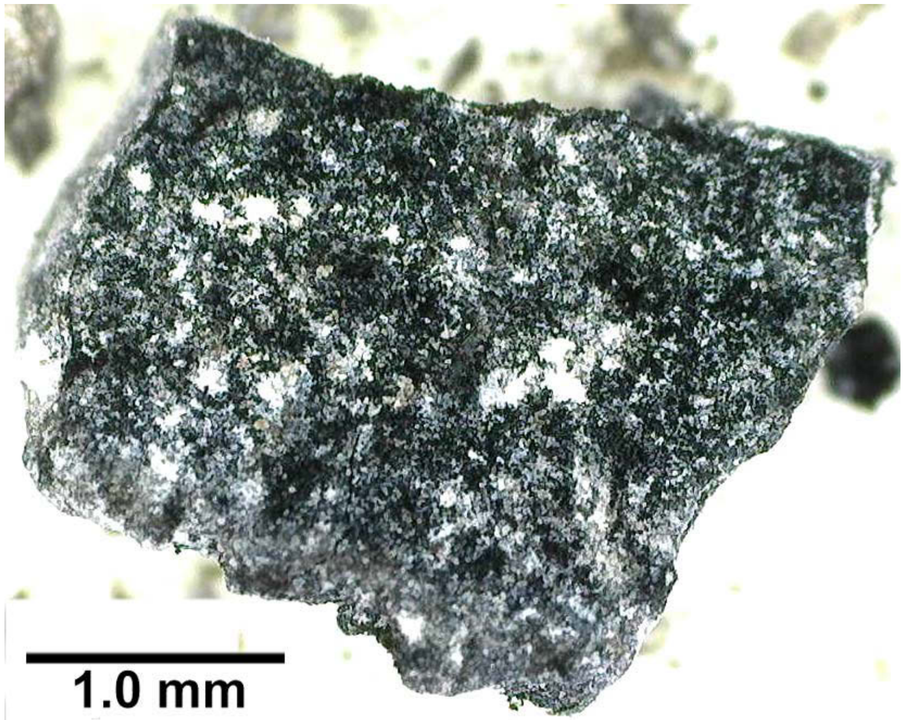


EF photomicrograph – Salt Wash #1-16 (Map #4), 8320-30 feet (interval tops not available), 3.0 visual epifluorescence rating in silty fine to medium crystalline dolomite, packstone/ wackestone with visible intercrystalline pores, bright oil fluorescence.

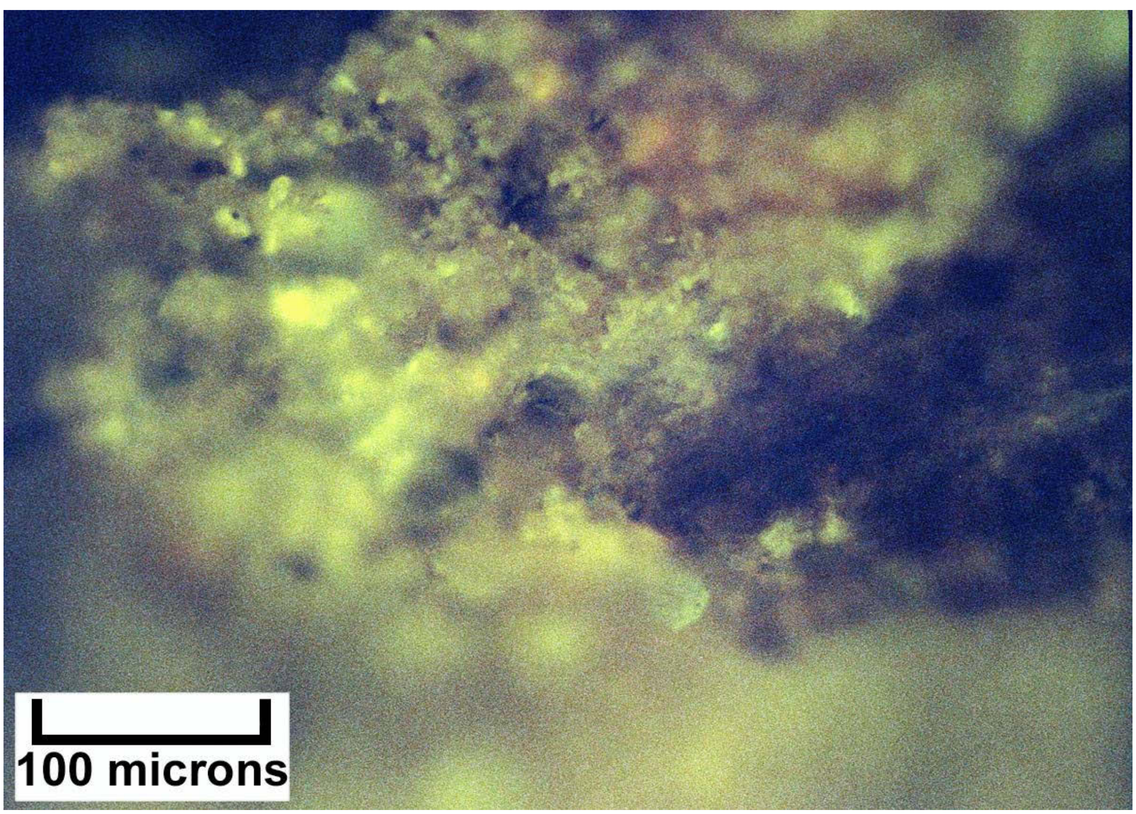
Digital microscope image (dry) – Kane Springs Federal #10-1 (Map #6), 8900-10 feet, A interval, light to medium gray, fine crystalline dolomite with microlaminations and sub-vertical filamentous microbial structures



EF photomicrograph – Kane Springs Federal #10-1 (Map #6), 8900-10 feet, A interval, 2.0 visual epifluorescence rating in microlaminated microbialite with visible pores and possible patchy anhydrite.

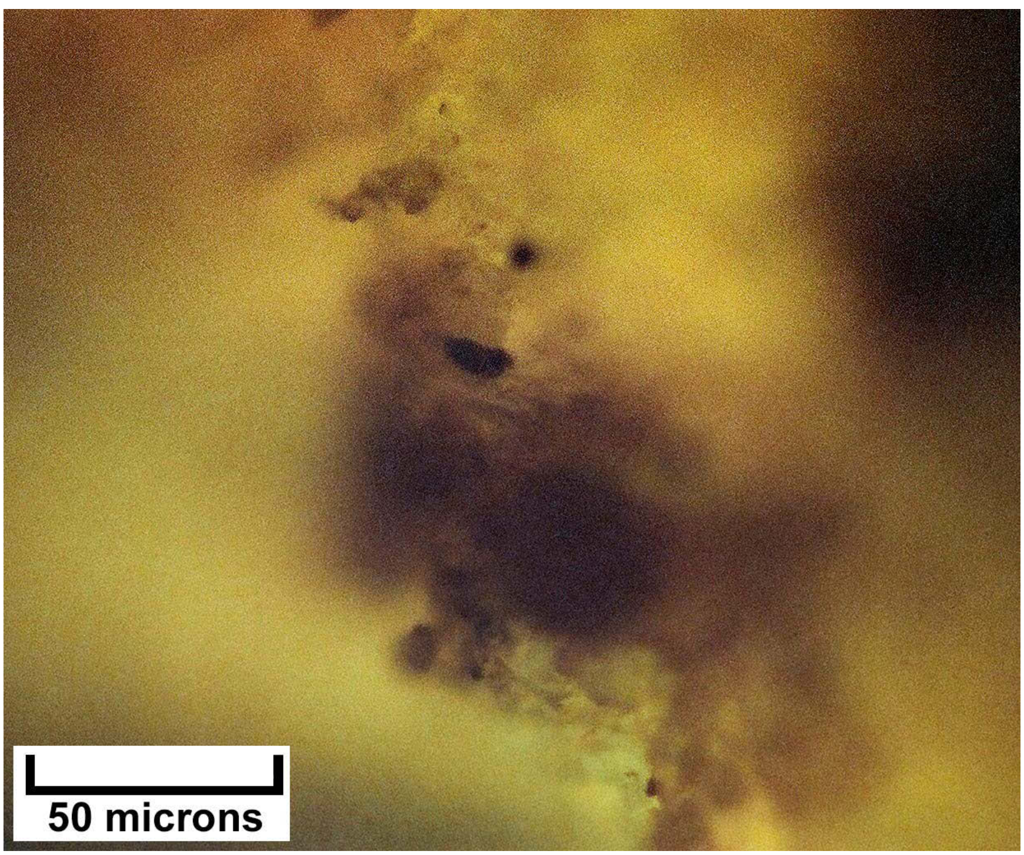


Digital microscope image (dry) – Kane Springs Federal #10-1 (Map #6), 8910-20 feet, B interval, light gray and black, organic-rich medium crystalline dolomite with vague hints of filamentous microbial structures, no visible porosity. Possible bitumen within some pores.

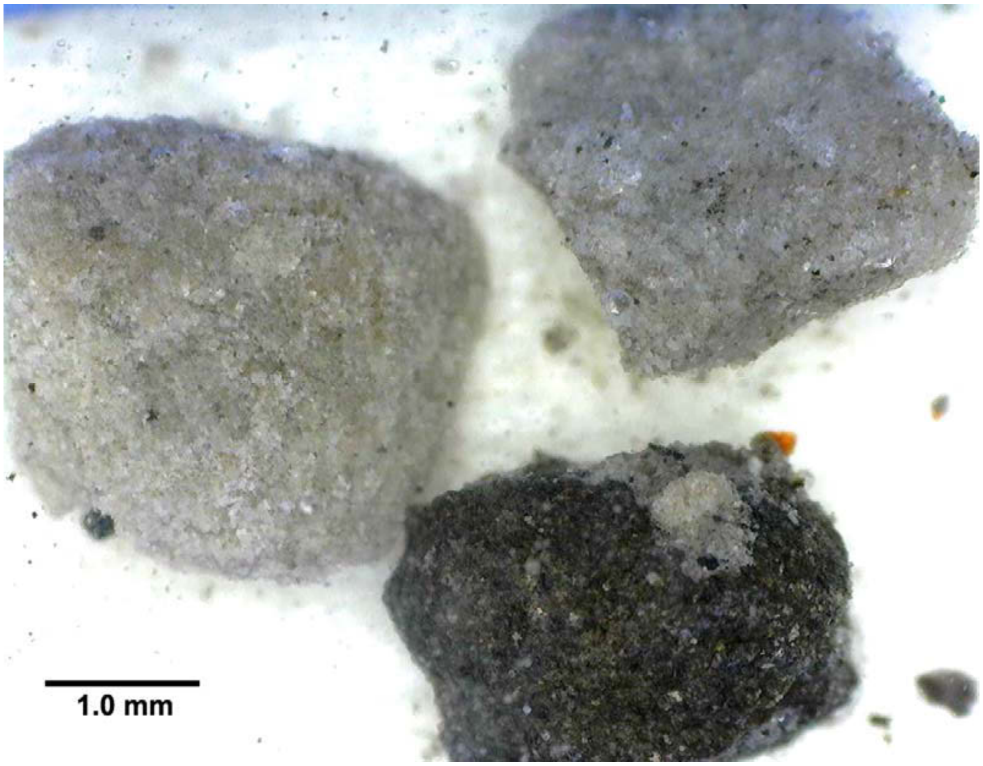


EF photomicrograph – Kane Springs Federal #10-1 (Map #6), 8910-20 feet, B interval, 2.5 visual epifluorescence rating microbial dolomite with bright fluorescence and visible pores, possible anhydrite.

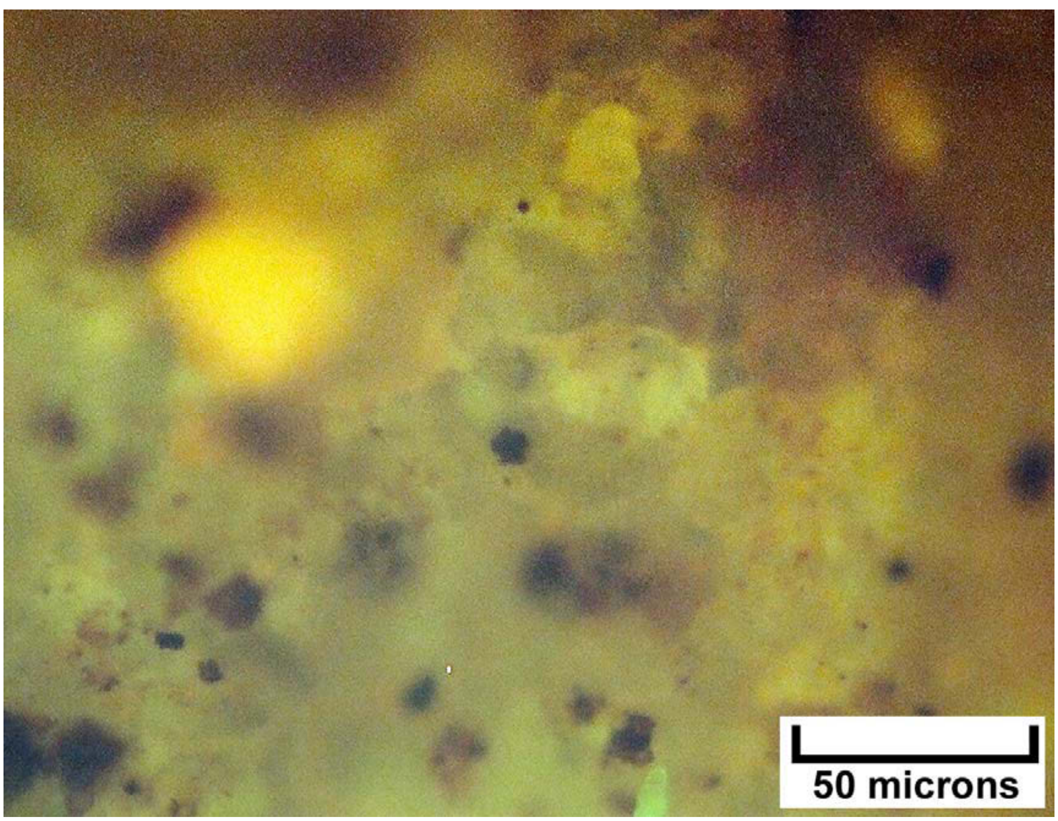
Digital microscope image (dry) – Utah #2 (Map #7), 7590-7600 feet, B interval, fine to medium crystalline dolomite, grainstone/packstone with possible fossil fragment, some visible intercrystalline pore space.



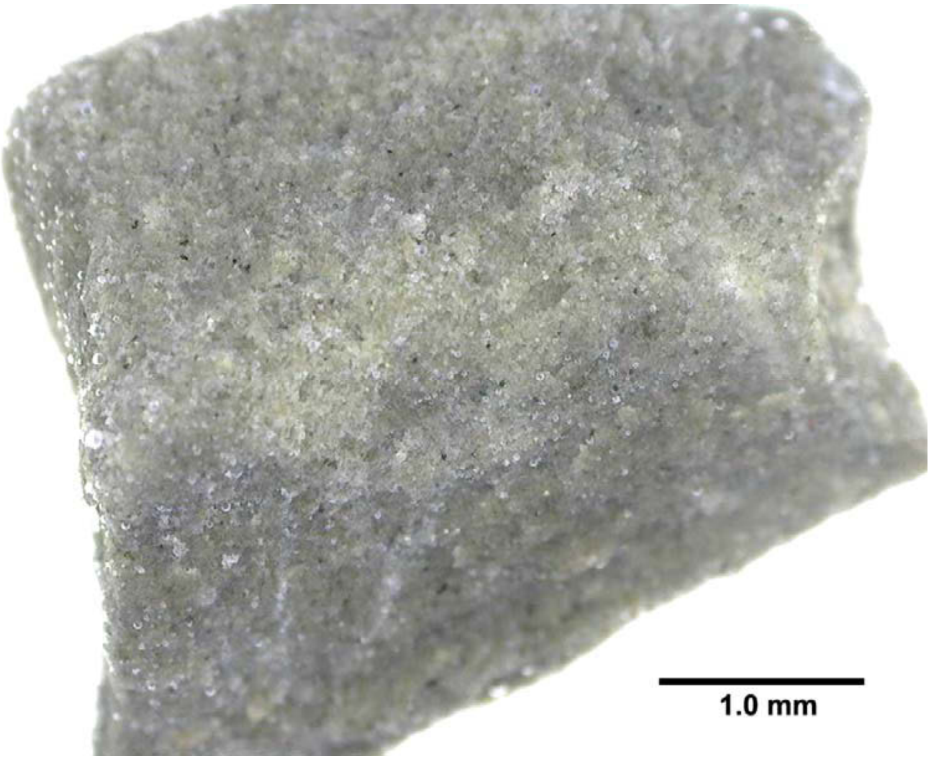
EF photomicrograph – Utah #2 (Map #7), 7590-7600 feet, A interval, 2.1 visual epifluorescence rating in medium crystalline dolomite patch within a slightly argillaceous siltstone.



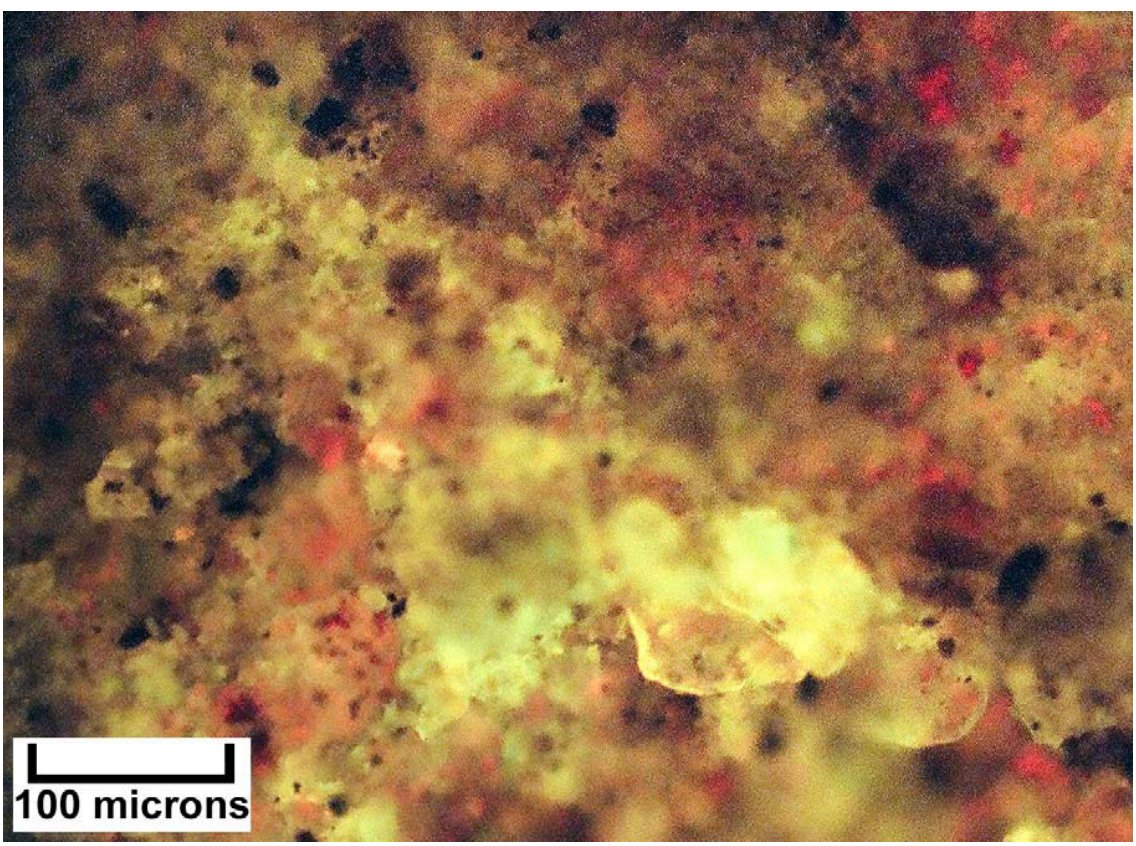
Digital microscope image (wet) – Utah #2 (Map #7), 7690-7700 feet, B interval, three cuttings samples showing dolomitic and argillaceous siltstone with variable dolomite crystal sizes.



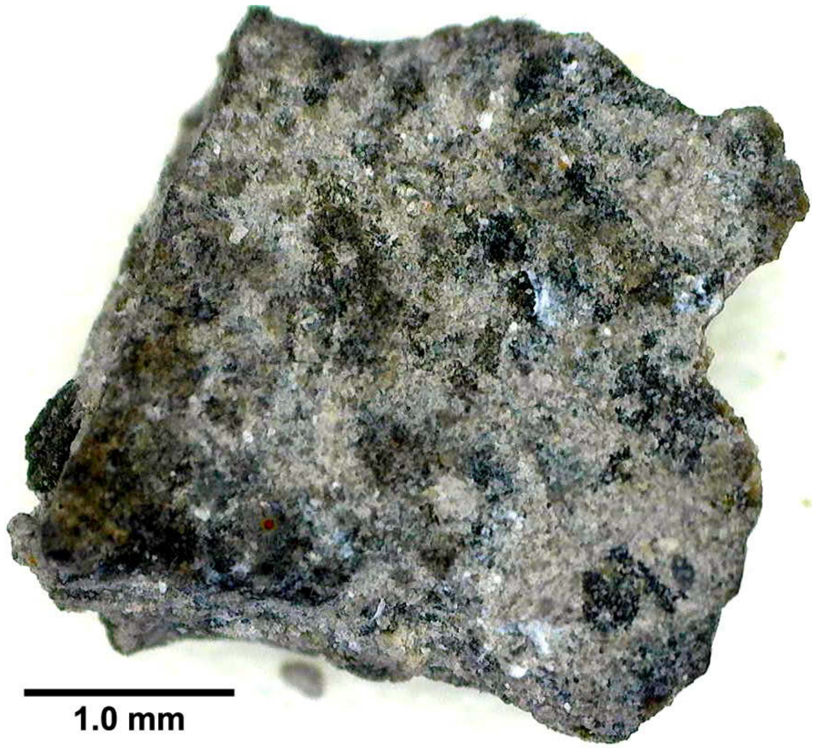
EF photomicrograph – Utah #2 (Map #7), 7690-7700 feet, B interval, 2.2 visual epifluorescence rating in finely crystalline dolomite, mudstone/wackestone with scattered silt grains. Note the small pyrite crystal clusters.



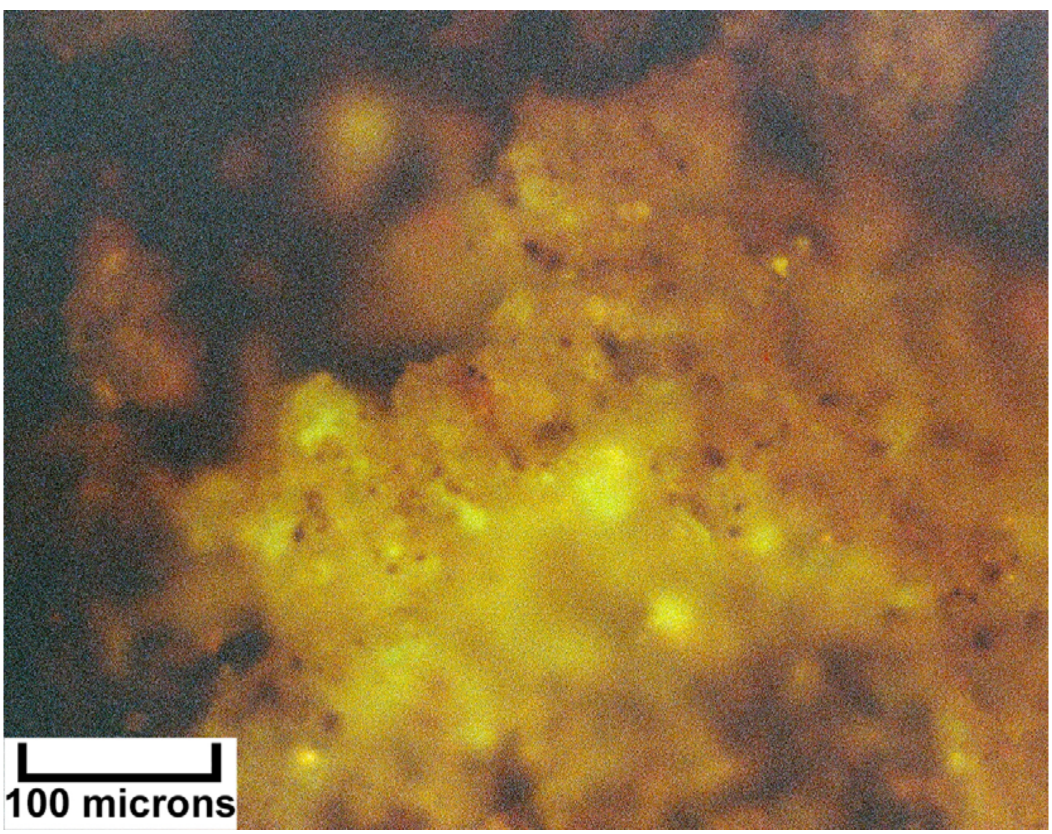
Digital microscope image (wet) – Utah #2 (Map #7), 7700-10 feet, B interval, light to medium gray, dolomitic siltstone with small patches containing visible porosity and oil staining.



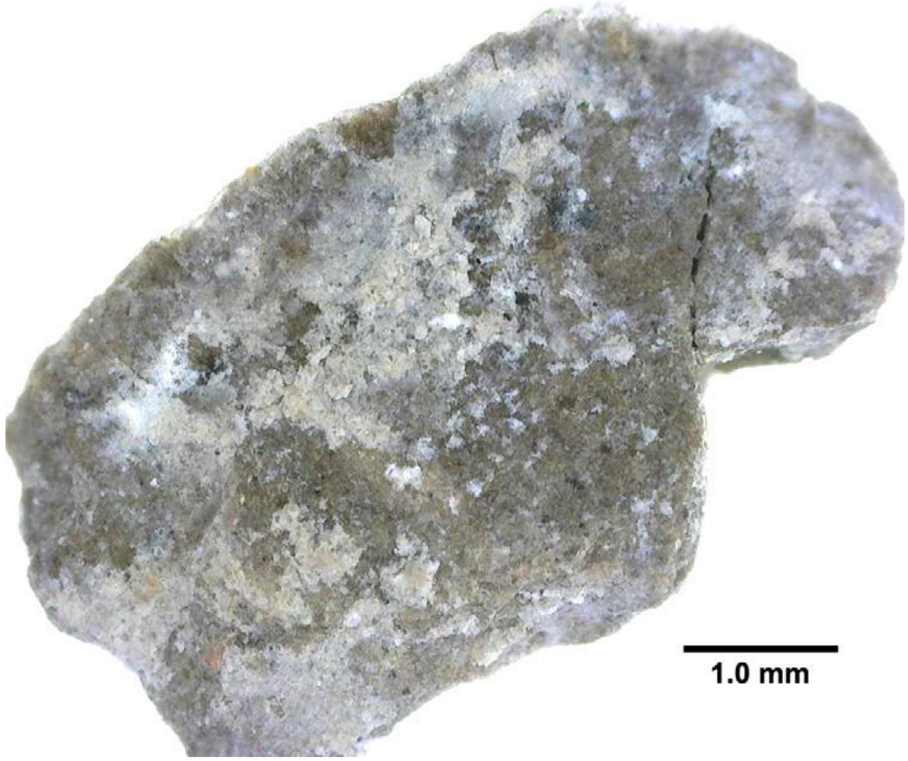
EF photomicrograph – Utah #2 (Map #7), 7700-10 feet, B interval, 2.3 visual epifluorescence rating in medium crystalline dolomite with good interparticle pores, packstone/grainstone. The reddish patches may be iron-rich.



Digital microscope image (dry) – Federal Bowknot #1 (Map #8), 6940-50 feet, B interval, light to medium gray, fine to medium crystalline dolomite with patches or layers of black argillaceous material and possible bitumen.

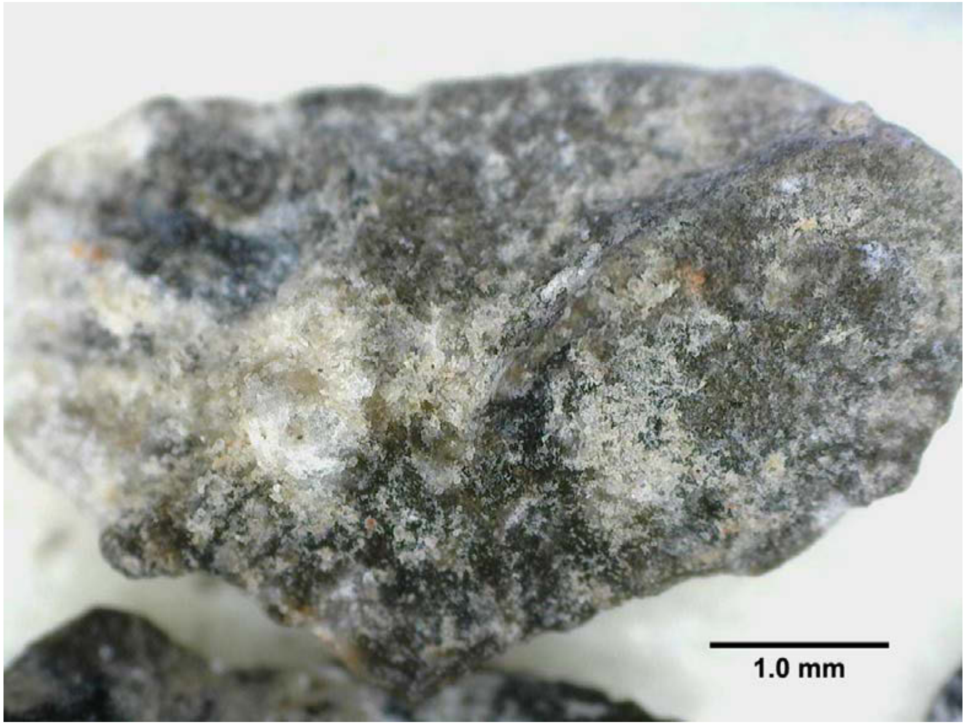


EF photomicrograph – Federal Bowknot #1 (Map #8), 6940-50 feet, B interval, 2.2 visual epifluorescence rating in medium crystalline dolomite crystal matrix.



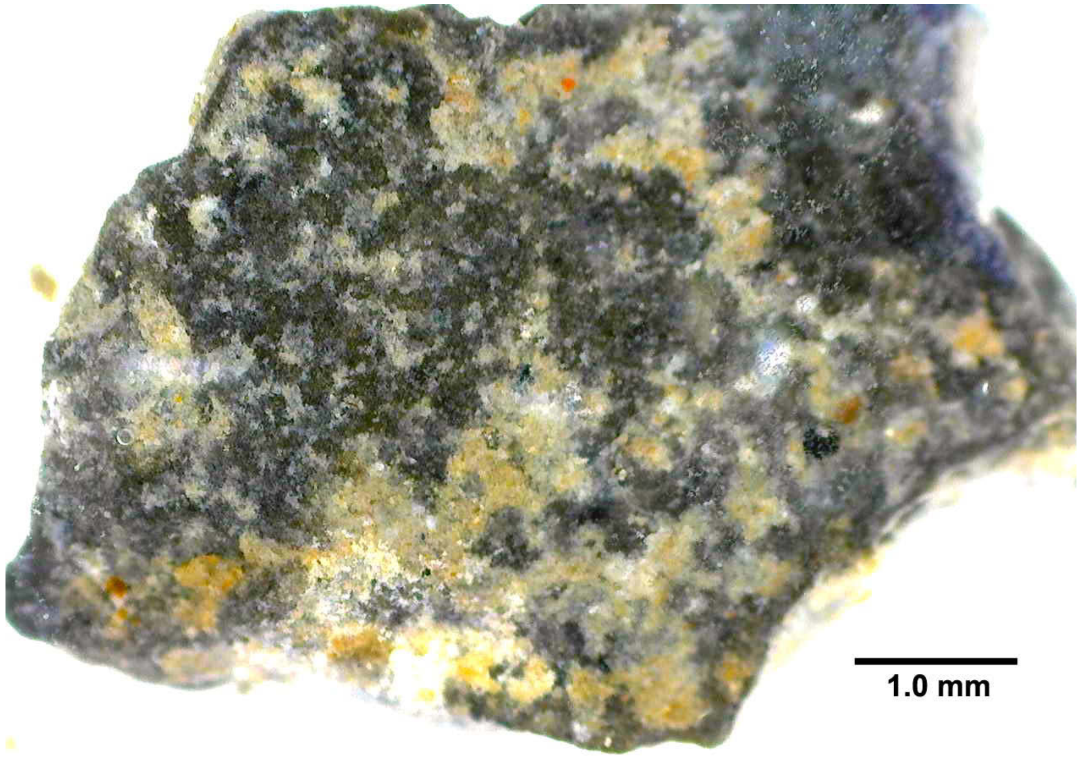
Digital microscope image (dry) – Federal Bowknot #1 (Map #8), 6960-70 feet, B interval, light to medium gray, finely crystalline silty dolomite with no visible porosity.

EF photomicrograph – Federal Bowknot #1 (Map #8), 6960-70 feet, B interval, 2.5 visual epifluorescence rating in dolomite with visible intercrystalline pores and live oil films.

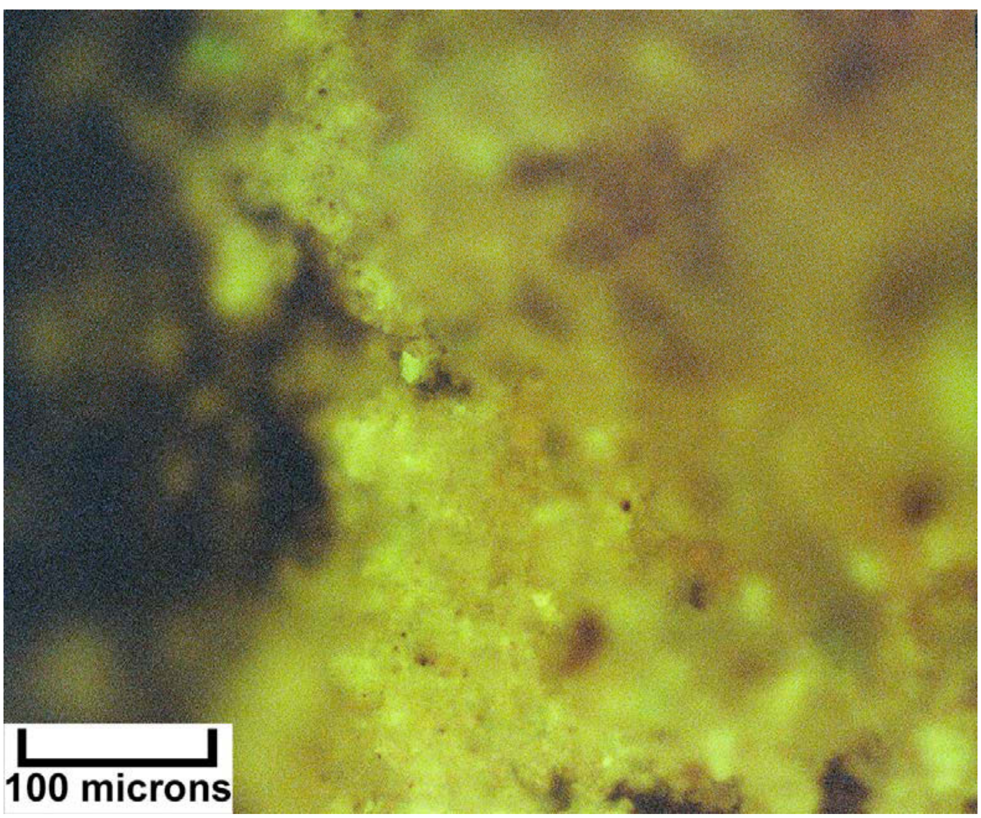


Digital microscope image (dry) – Federal Bowknot #1 (Map #8), 6970-75 feet, B interval, medium to dark gray, silty, argillaceous and anhydritic dolomite with wispy seam stylolites.

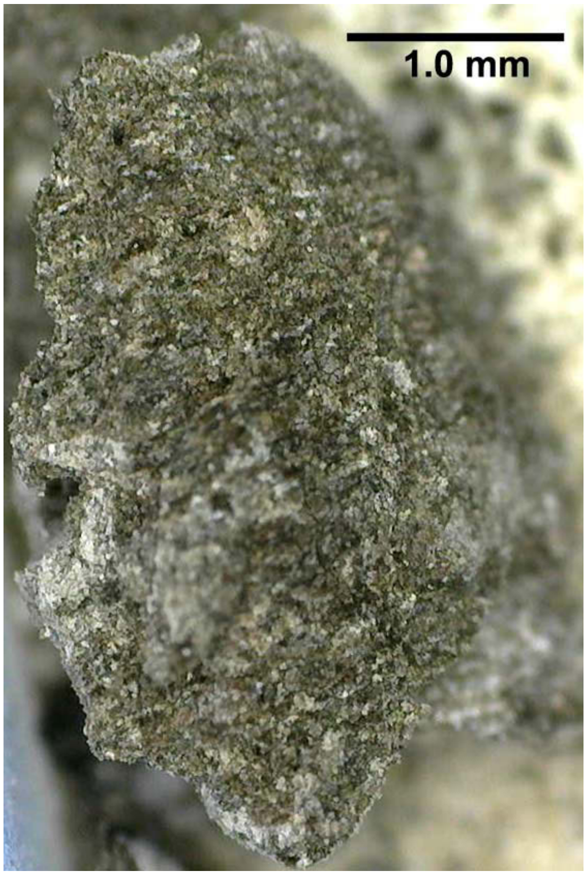
EF photomicrograph – Federal Bowknot #1 (Map #8), 6970-75 feet, B interval, 2.4 visual epifluorescence rating in silty dolomite with stylolites.



Digital microscope image (wet) – Federal Bowknot #1 (Map #8), 7000-10 feet, C interval, medium to dark gray, microcrystalline dolomite with lumpy patches of possible thrombolitic texture.



EF photomicrograph – Federal Bowknot #1 (Map #8), 7000-10 feet, C interval, 2.4 visual epifluorescence rating in microcrystalline microbial dolomite.

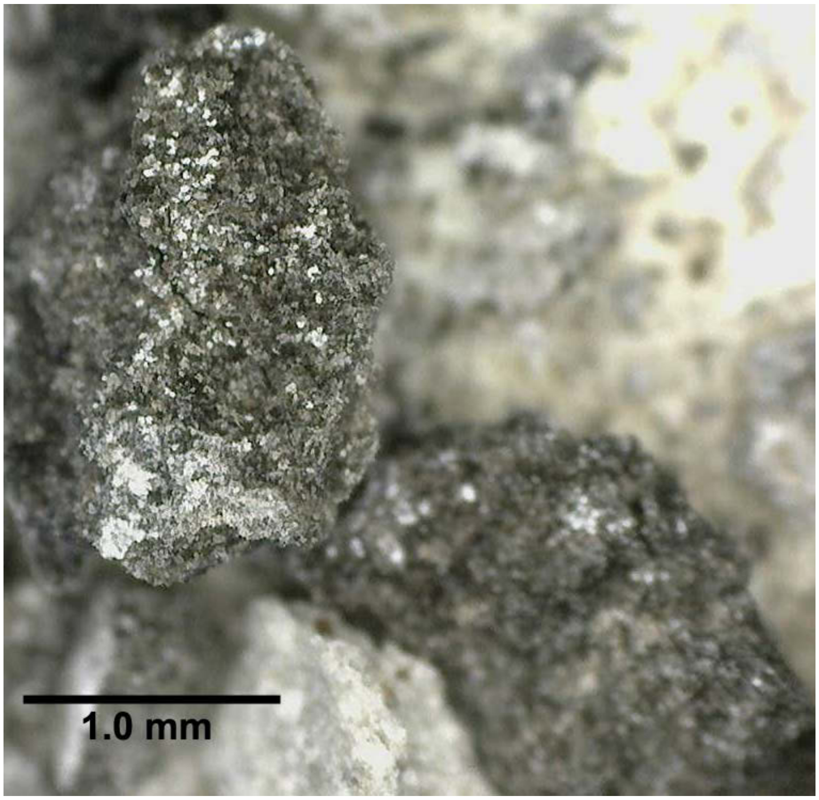


Digital microscope image (dry) – Kane Springs #25-19-34-1 (Map #9), 7560-70 feet (horizontal well), medium to dark gray, finely crystalline silty dolomite with ax-head crystals of anhydrite.

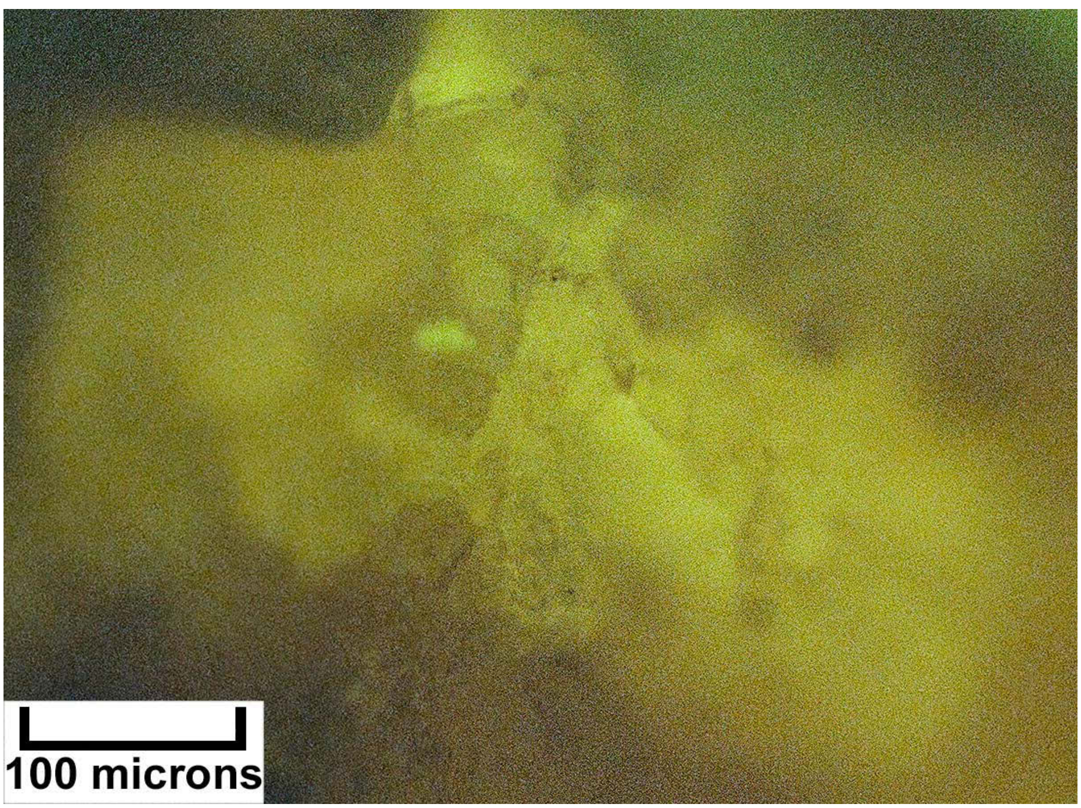
EF photomicrograph – Kane Springs Federal #25-19-34-1 (Map #9), 7560-70 feet (horizontal well), 3.0 visual epifluorescence rating in cluster of dolomite crystals.

Digital microscope image (dry) – Kane Springs #25-19-34-1 (Map #9), 7570-80 feet (horizontal well), two cuttings, the upper consists of dark gray to black microcrystalline dolomite, commonly massive; lower sample is medium dark gray, medium crystalline dolomitic wackestone/ packstone. Some of the back material in both samples may be bitumen.

EF photomicrograph – Kane Springs Federal #25-19-34-1 (Map #9), 7570-80 feet (horizontal well), 3.4 visual epifluorescence rating in microcrystalline dolomite with bright fluorescing oil films and halos.

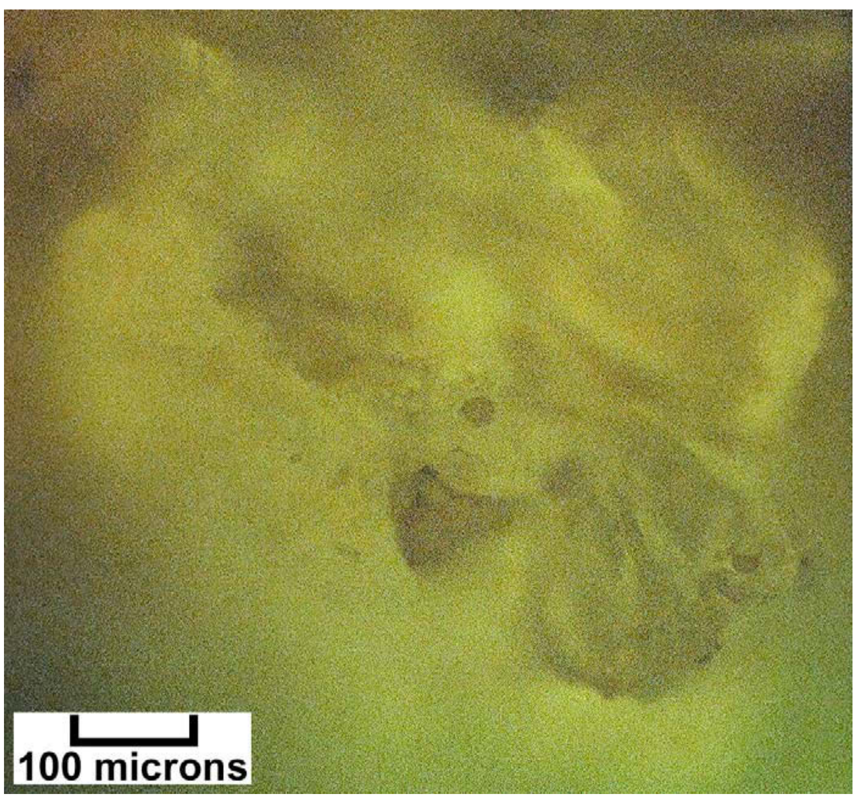


Digital microscope image (dry) – Kane Springs #25-19-34-1 (Map #9), 7580-90 feet (horizontal well), medium to dark gray, organic-rich dolomite with probable microbial boxwork and linear filaments.

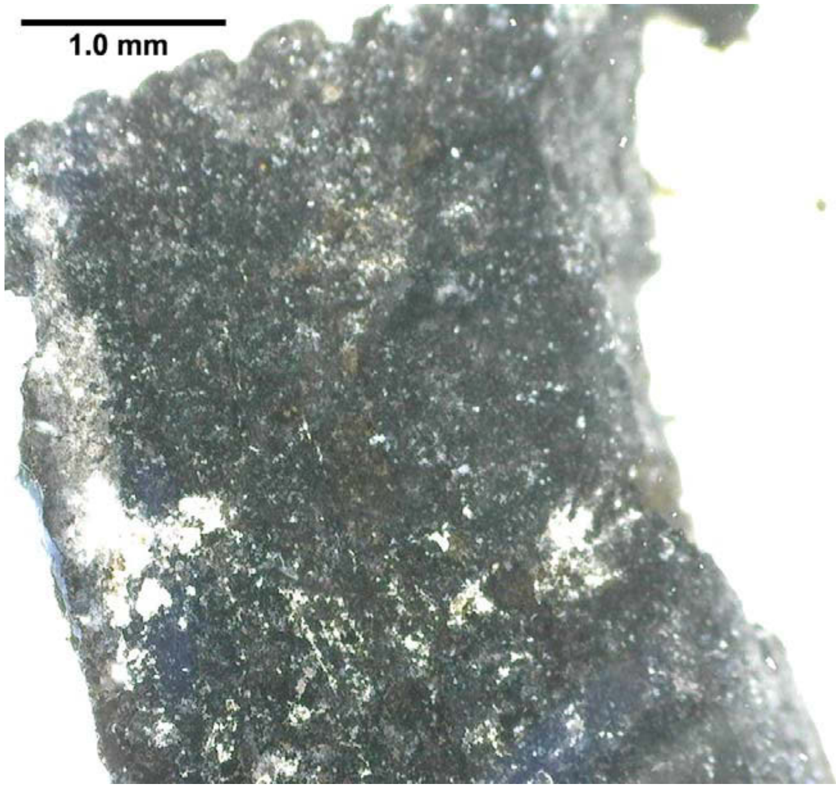


EF photomicrograph – Kane Springs Federal #25-19-34-1 (Map #9), 7580-90 feet (horizontal well), 3.0 visual epifluorescence rating in honeycomb remnants of microbial filaments.

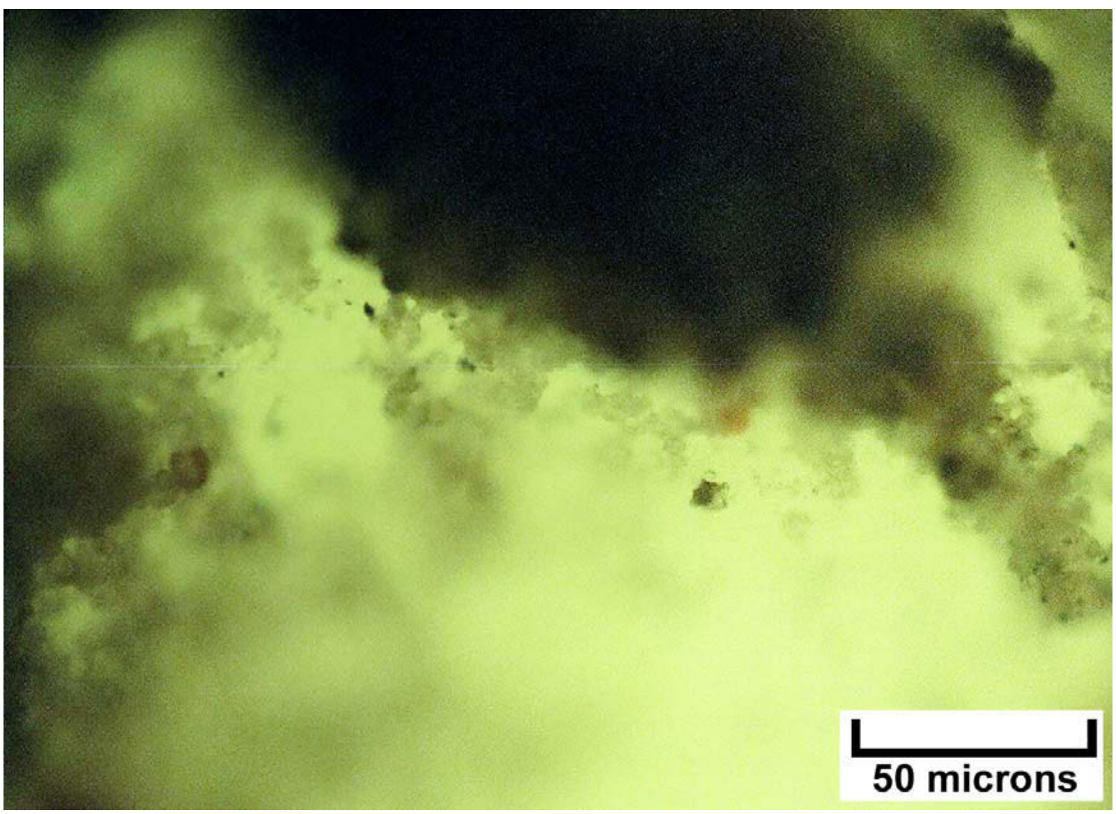
Digital microscope image (dry) – Kane Springs #25-19-34-1 (Map #9), 7600-10 feet (horizontal well), two cuttings in this image show a clean micro- to medium crystalline dolomite with packstone/ grainstone fabric on the left and a dark argillaceous microcrystalline dolomite with a wackestone or possible microbial fabric.



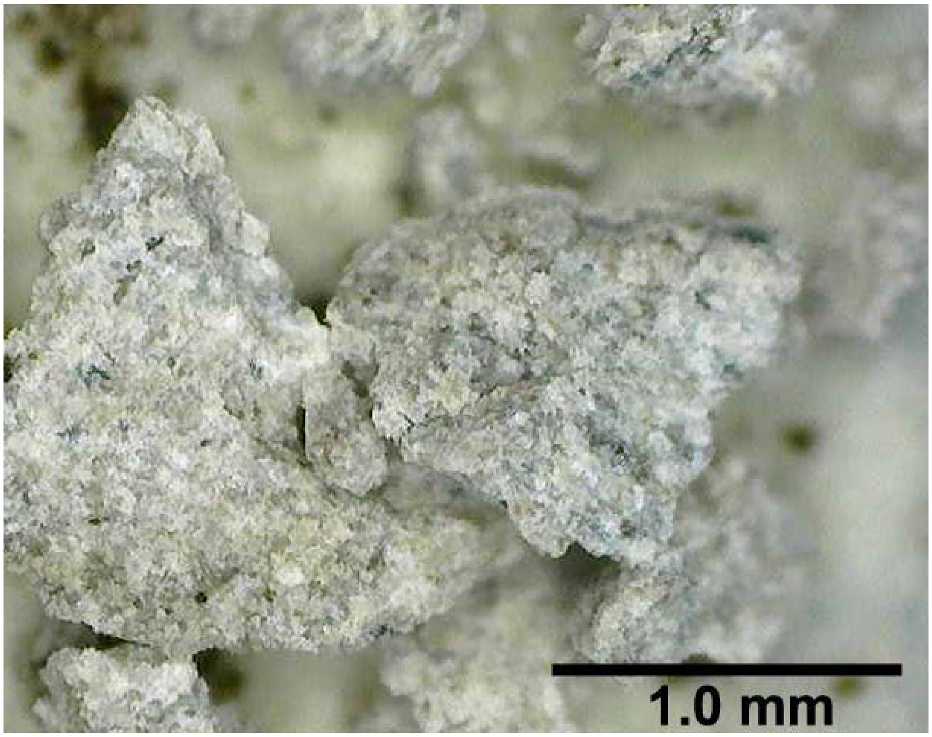
EF photomicrograph – Kane Springs Federal #25-19-34-1 (Map #9), 7600-10 feet (horizontal well), 3.0 visual epifluorescence rating in microlaminated microbial(?) texture; note alternating epifluorescence and microlamination.



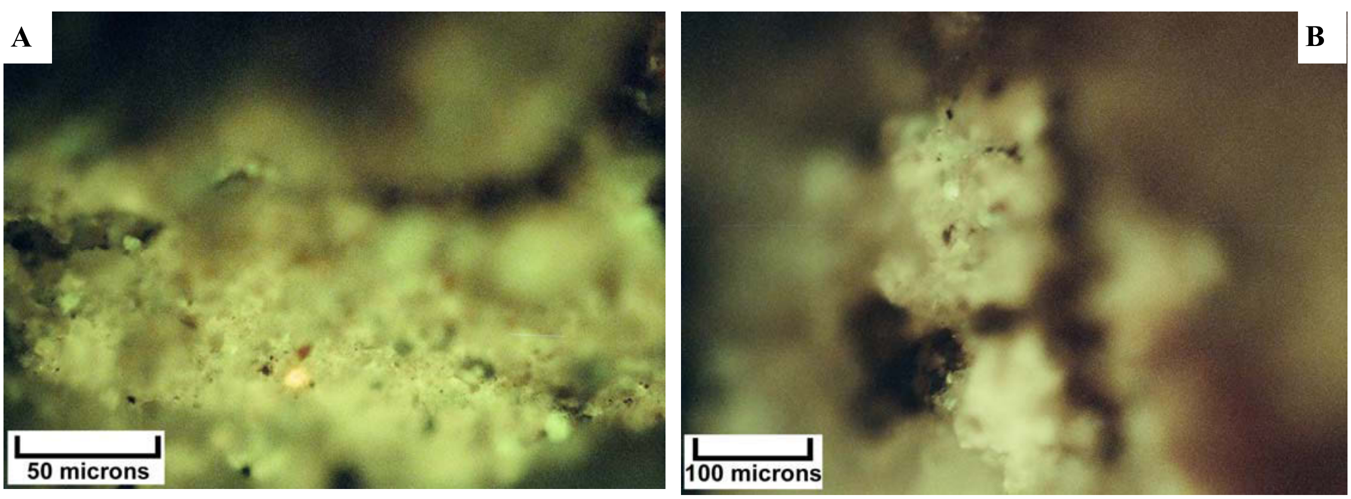
Digital microscope image (wet) – Kane Springs #25-19-34-1 (Map #9), 7730-40 feet (horizontal well), dark gray, organic-rich to argillaceous dolomite with a possible lumpy microbial or pisolitic texture.



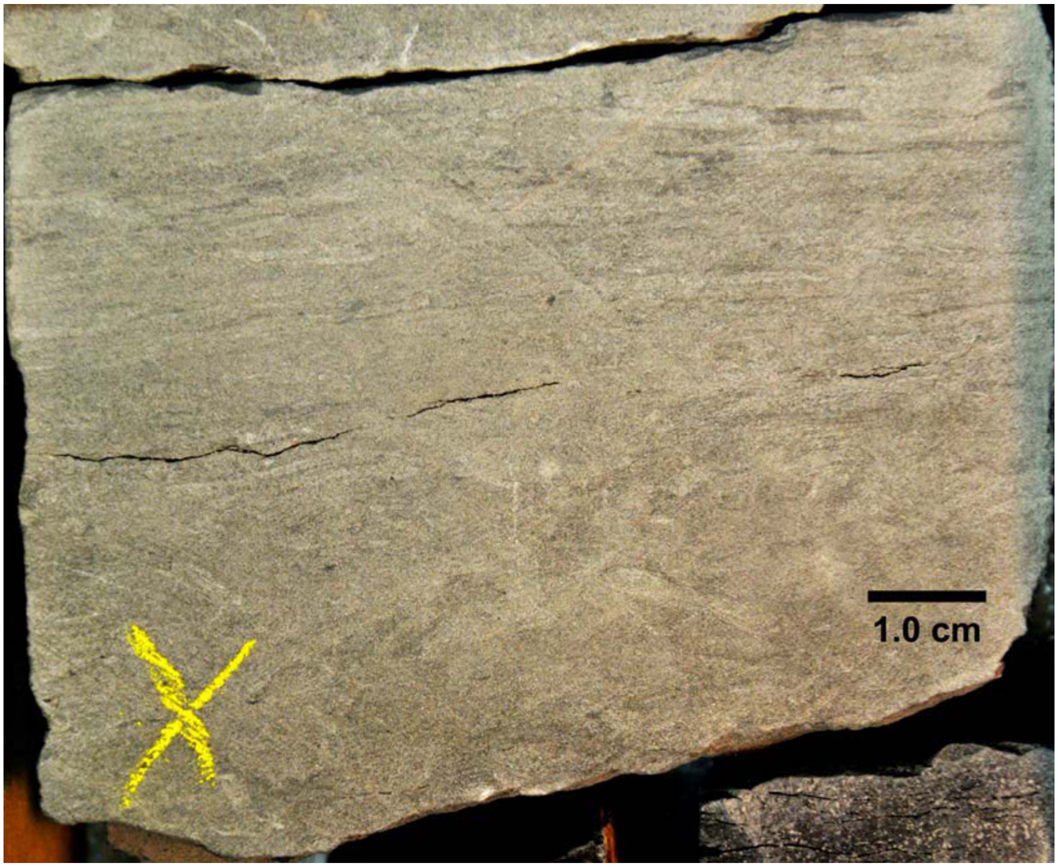
EF photomicrograph – Kane Spring #25-19-34-1 (Map #9), 7730-40 feet (horizontal well), 2.6 visual epifluorescence rating in patch of crystalline dolomite displaying a bright yellow fluorescing oil film.



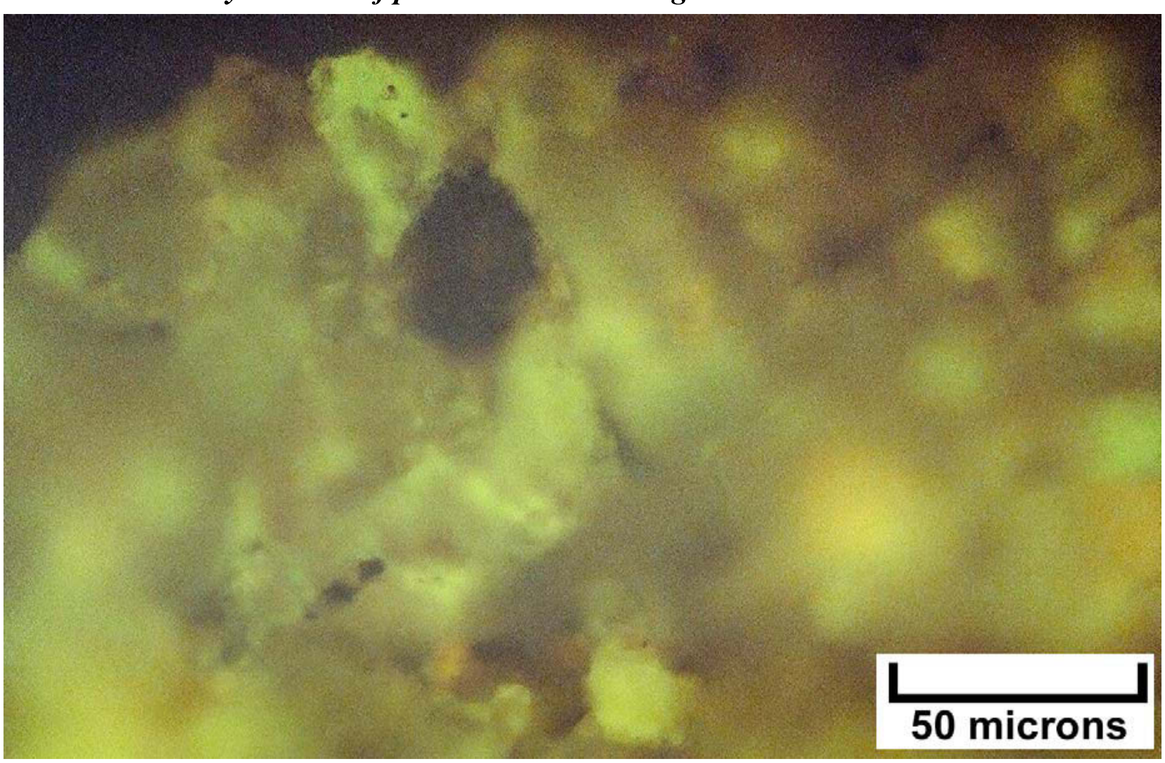
Digital microscope image (dry) – Kane Springs #25-19-34-1 (Map #9), 7740-50 feet (horizontal well), two cuttings showing light gray, fine to medium crystalline dolomite, probable packstone/wackestone fabric with possible microbial boxwork.



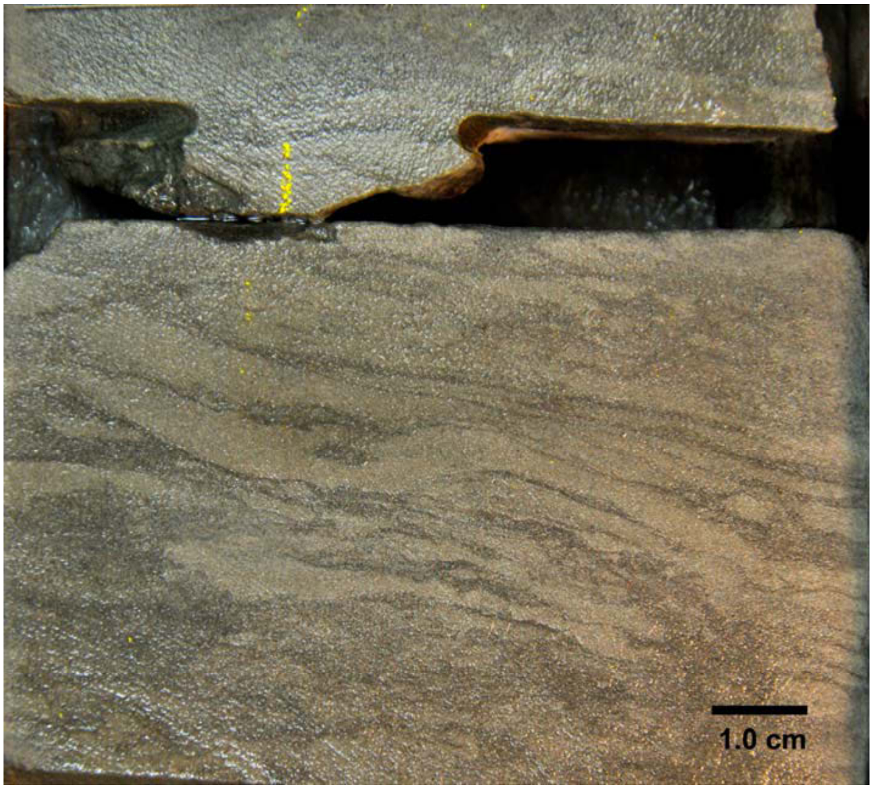
EF photomicrographs – Kane Spring #25-19-34-1 (Map #9), 7740-50 feet (horizontal well). A: 2.8 visual epifluorescence rating in fluorescent dolomitic patch. B: 2.3 visual epifluorescence rating in dolomitic patch containing "dead" argillaceous matrix.



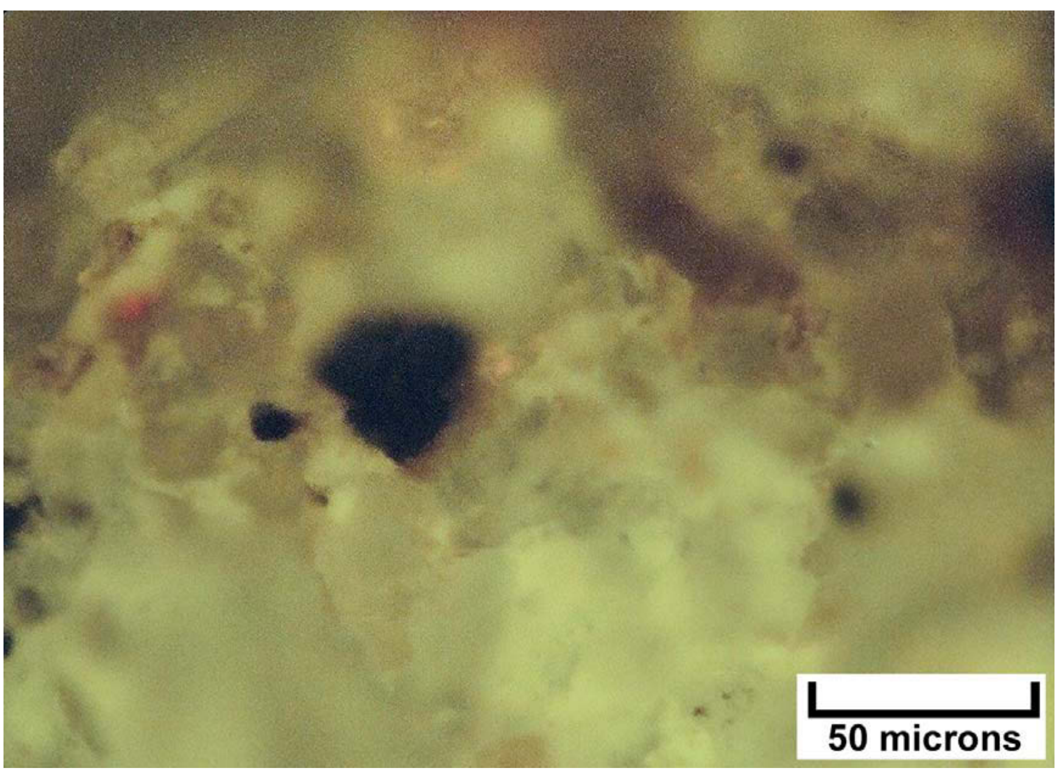
Close-up image (dry) of slabbed core – Cane Creek Unit #26-3 (Map 10), 7410.4 feet, B interval, silty dolomite with light brown oil staining. Note the bed of oncolites and other grains at the base overlain by laminae of possible microbial origin.



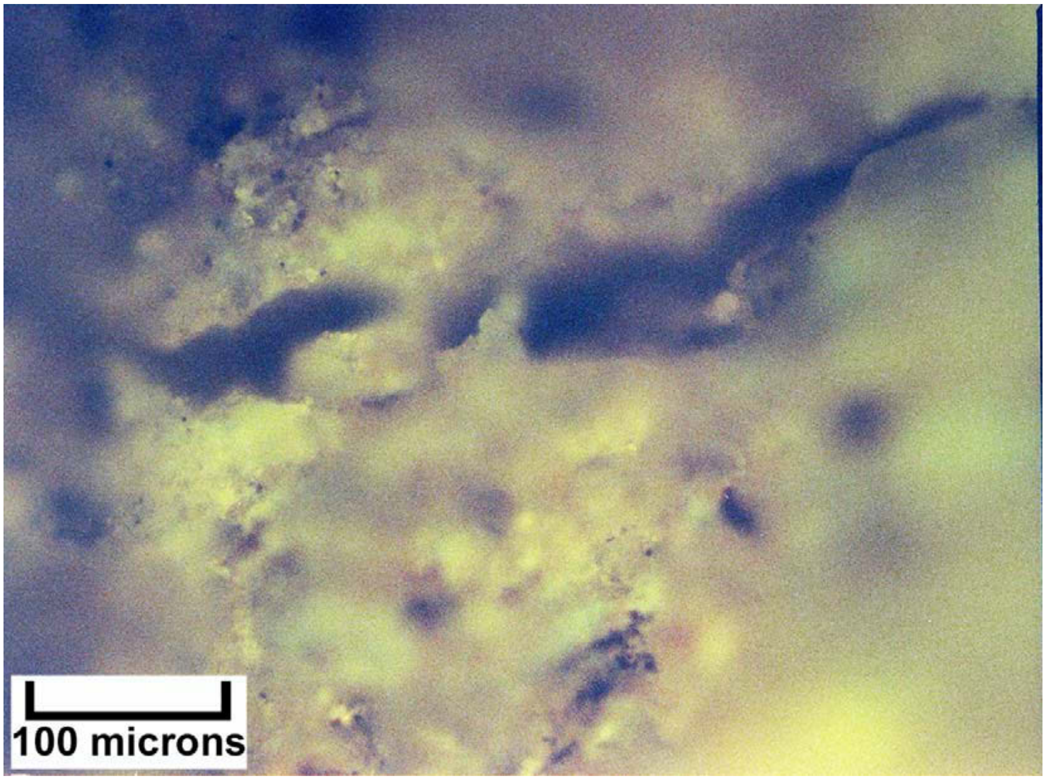
EF photomicrograph – Cane Creek Unit #26-3 (Map #10), 7410.4 feet, B interval, 2.6 visual epifluorescence rating in silty dolomite, medium crystalline with good visible porosity.



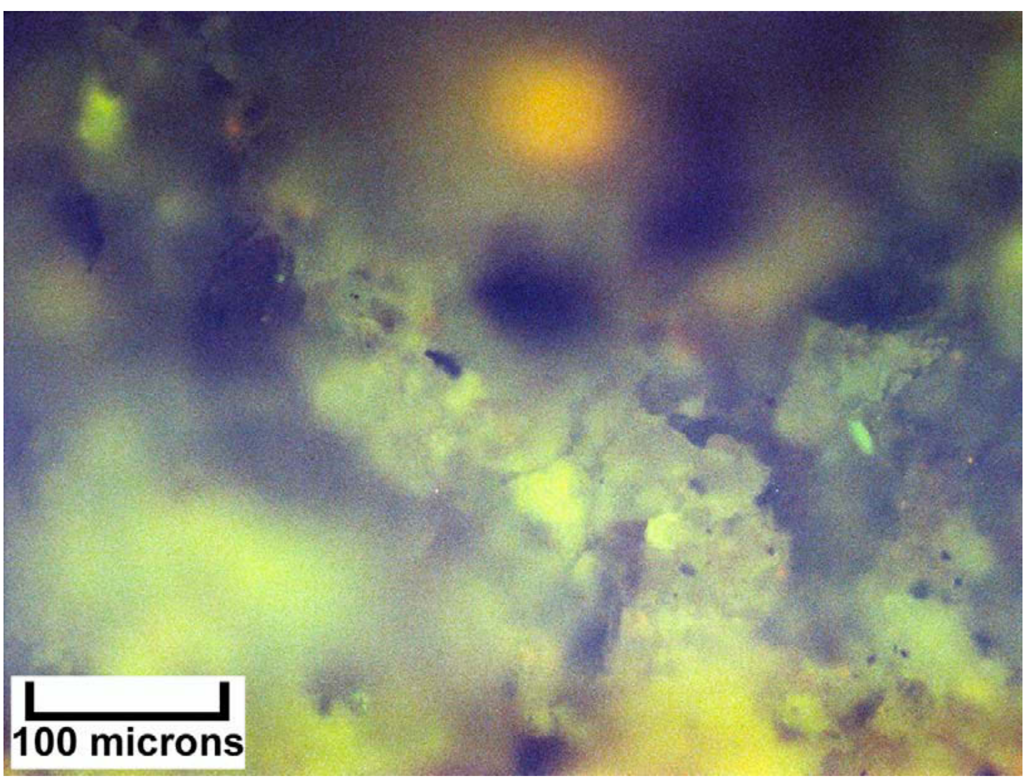
Close-up image (wet) of slabbed core – Cane Creek Unit #26-3 (Map 10), 7428.1 feet, B interval, silty dolomite with light brown oil staining. Relict laminae with bioturbation in this segment. Note the dark gray areas which consist of bitumen within the intercrystalline pores of the dolomite.



EF photomicrograph – Cane Creek Unit #26-3 (Map #10), 7428.1 feet, B interval, 2.6 visual epifluorescence rating in medium crystalline dolomite with visible pore space, possible microbialite structure containing disseminated pyrite.

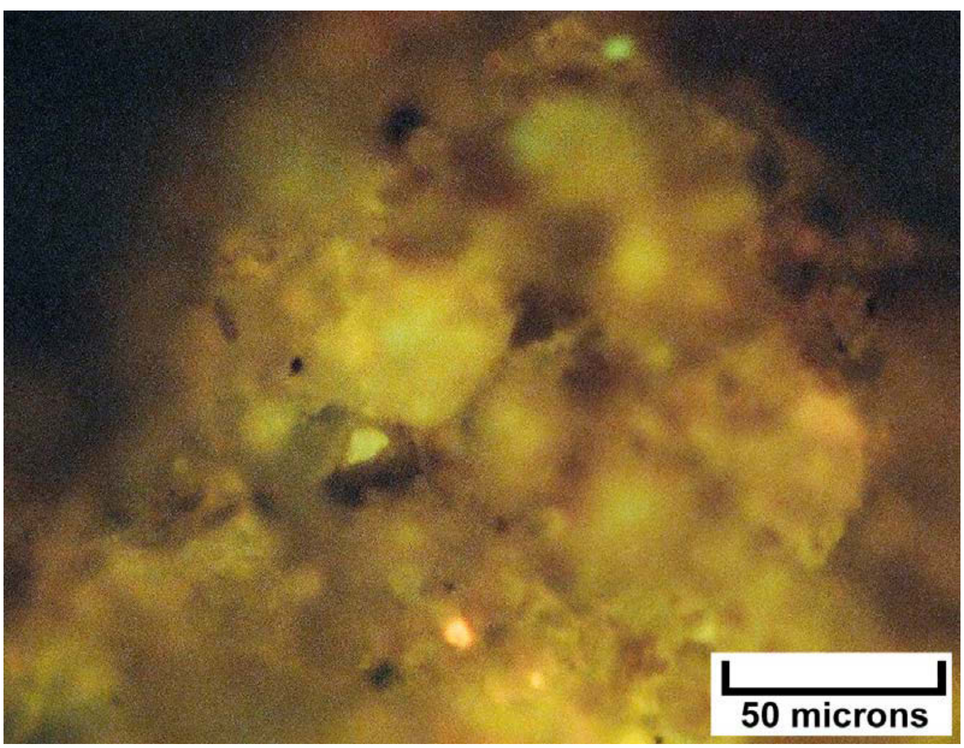


EF photomicrograph of uncovered thin section – Cane Creek Unit #26-3 (Map #10), 7430.9 feet, B interval, 3.5 visual epifluorescence rating, silty dolomite with ostracod shells and anhydrite-filled fractures.



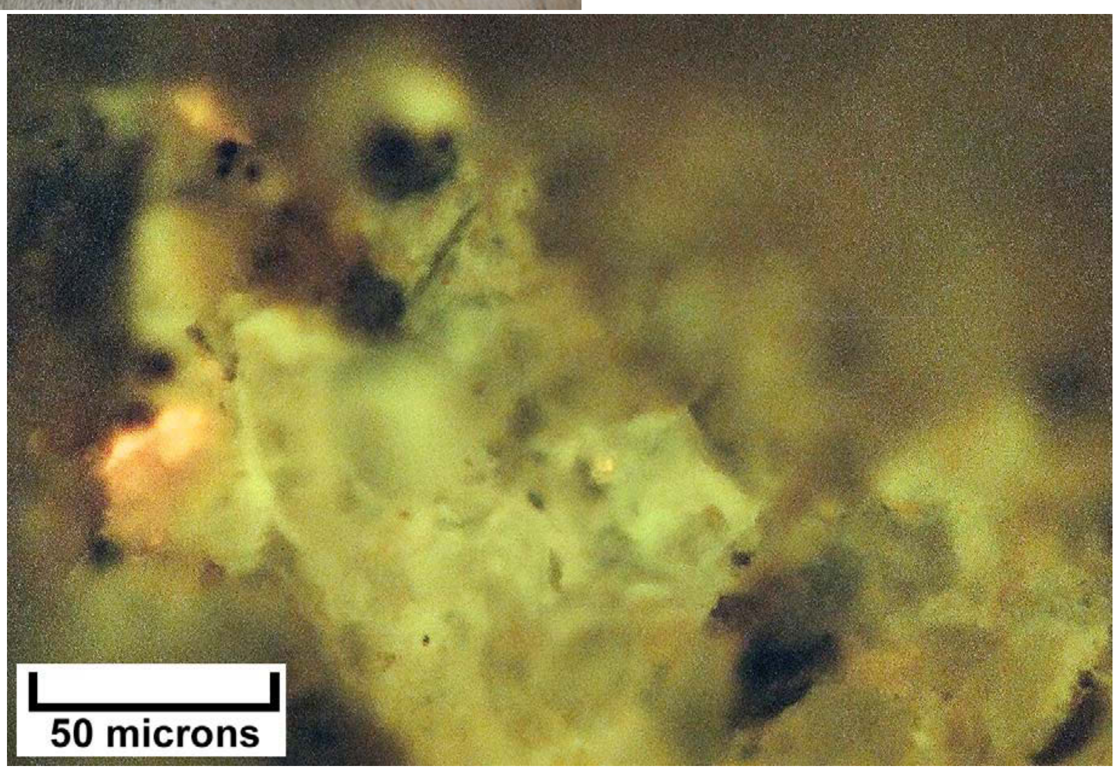
EF photomicrograph of uncovered thin section – Cane Creek Unit #26-3 (Map #10), 7439 feet, B interval, 3.3 visual epifluorescence rating, silty dolomite with ostracod shells.

Close-up image (dry) of slabbed core – Cane Creek Unit #26-3 (Map 10), 7437.5 feet, B interval, dolomite with light brown oil staining that overlies a thin, organic black shale bed. Note the wavy microbially induced laminations, partially outlined with dark bitumen-lined pores.

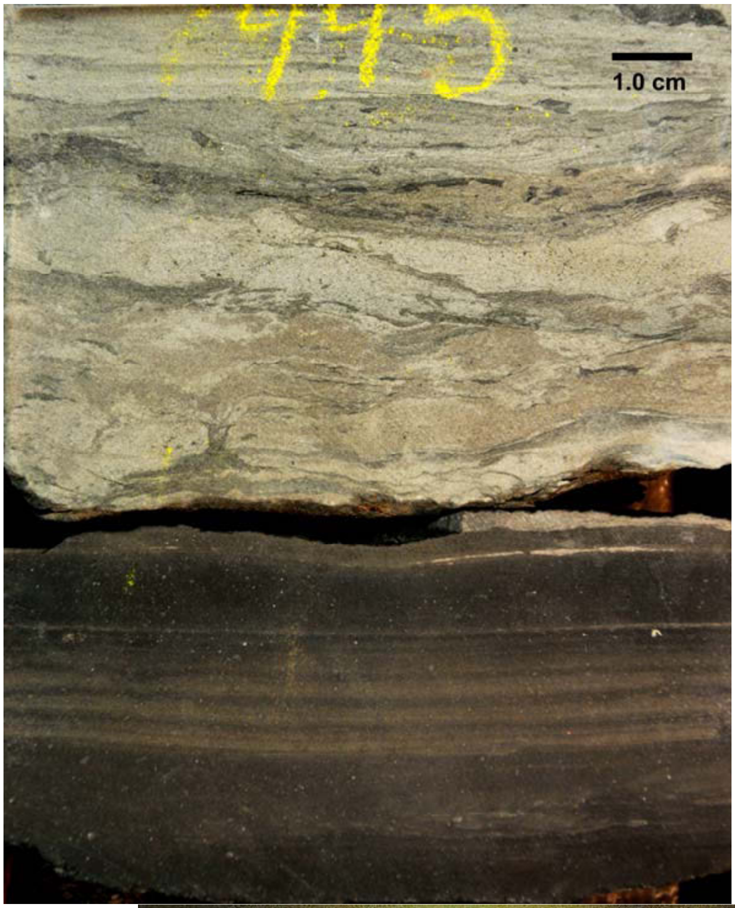


EF photomicrograph – Cane Creek Unit #26-3 (Map #10), 7437.5 feet, B interval, 2.8 visual epifluorescence rating in medium crystalline microbial dolomite with intercrystalline porosity and fluorescence.

Close-up image (wet) of slabbed core – Cane Creek Unit #26-3 (Map 10), 7440.5 feet, B interval, dolomitic siltstone with light and variable oil staining. Note the ripple-laminated thin beds that display bioturbated tops. Oil staining seems to be best developed in the burrowed bed caps. The vertical fractures are partially lined with anhydrite.



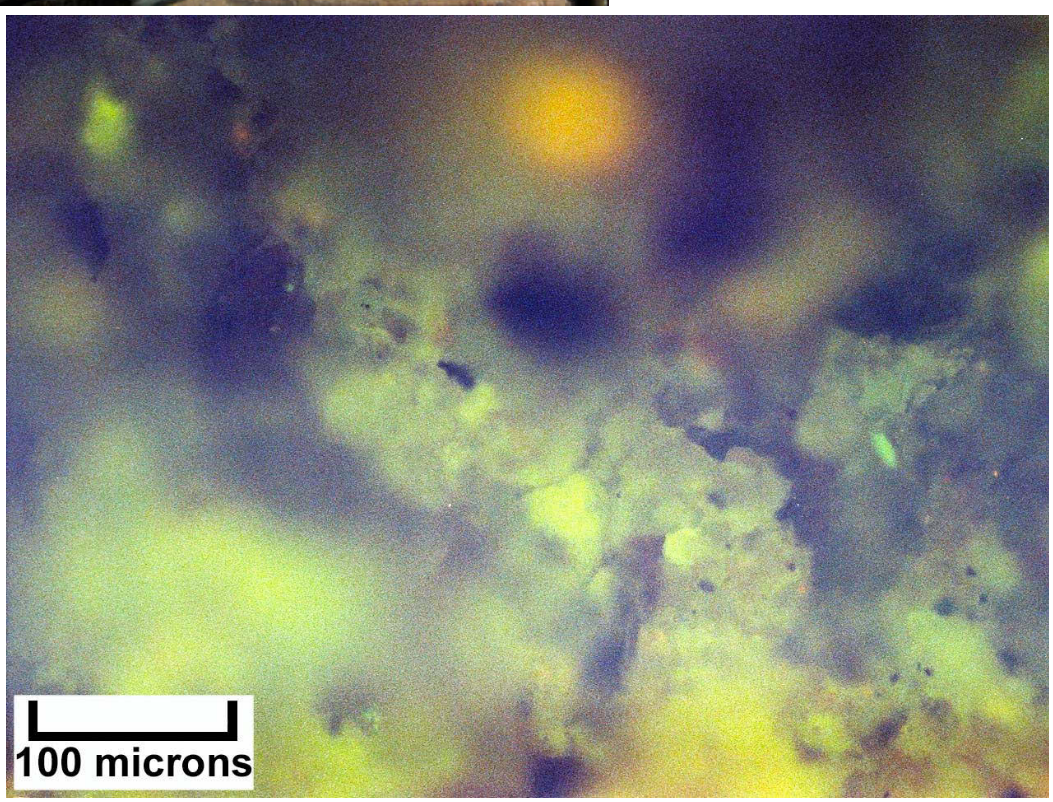
EF photomicrograph – Cane Creek Unit #26-3 (Map #10), 7440.5 feet, B interval, 2.6 visual epifluorescence rating in medium crystalline dolomite, probable microbial textures with good visible open pores.



Close-up image (dry) of slabbed core – Cane Creek Unit #26-3 (Map 10), 7445.1 feet, B interval, black organic-rich shale with brown dolomitic laminae overlain by light-colored silty dolomite with patchy oil staining. Small microbial stromatolites, separated by desiccation cracks.

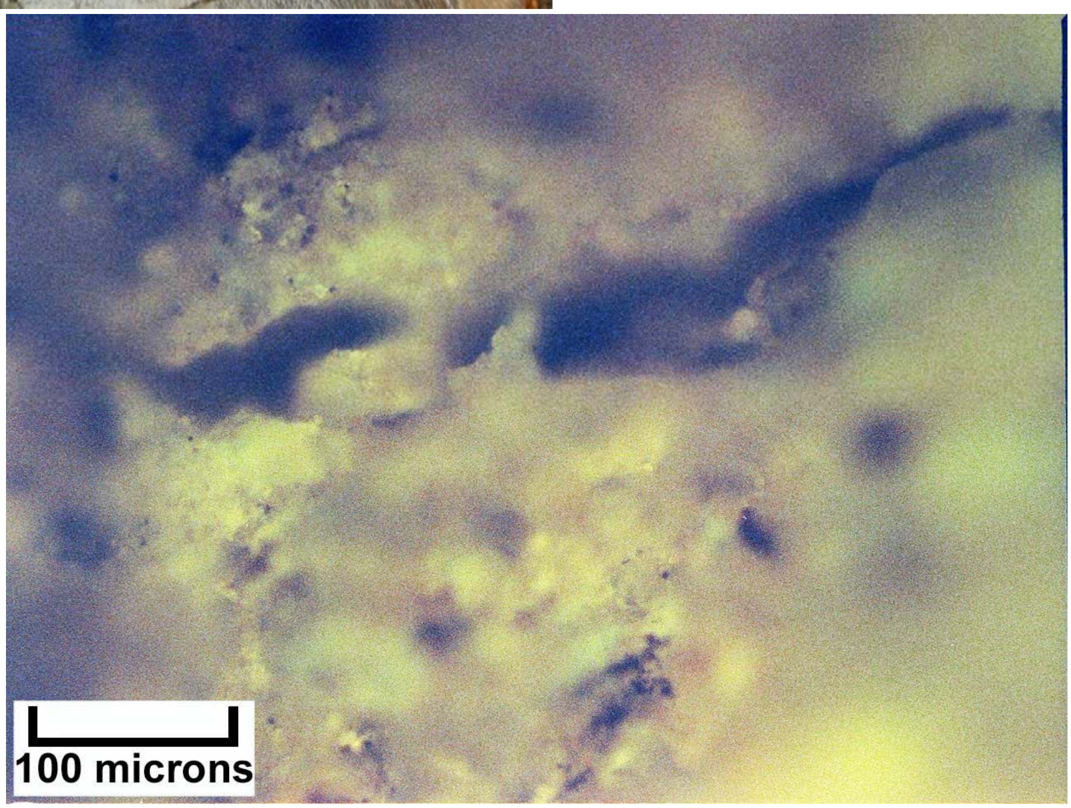
EF photomicrograph – Cane Creek Unit #26-3 (Map #10), 7445.1 feet, B interval, 3.0 visual epifluorescence rating in medium crystalline dolomite with probable microbial structures, rare floating silt grains and very bright fluorescence.

Close-up image (wet) of slabbed core – Cane Creek Unit #26-3 (Map 10), 7456.0 feet, B interval, silty dolomite with probable microbial structures that range from small wavy stromatolites (laminated) to thrombolites (clotted). Some of the dark gray concentrations are the result of bitumen within matrix pore spaces. The broken nature of this core interval may indicate the presence of vertical fracture sets.

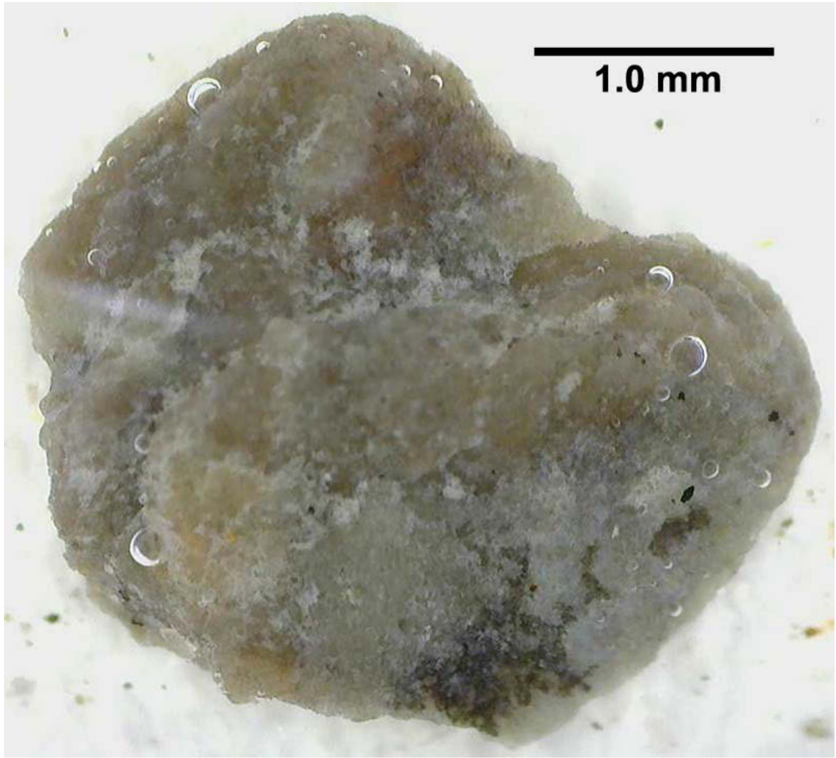


EF photomicrograph – Cane Creek Unit #26-3 (Map #10), 7456 feet, C interval, 2.1 visual epifluorescence rating in medium crystalline dolomite, possible microbial texture with excellent visible porosity.

Close-up image (dry) of slabbed core – Cane Creek Unit #26-3 (Map 10), 7469.2 feet, C interval, silty to argillaceous dolomite with patchy light brown oil staining. The lower portion of this segment consists of wavy laminations (stromatolitic)which are overlain by a distinctive clotted (thrombolitic) fabric. Note the vertical fracture on the left side of the segment that is lined with anhydrite.



EF photomicrograph – Cane Creek Unit #26-3 (Map #10), 7469.2 feet, C interval, 2.2 visual epifluorescence rating in anastomosing linear pore network associated with the microbial texture.

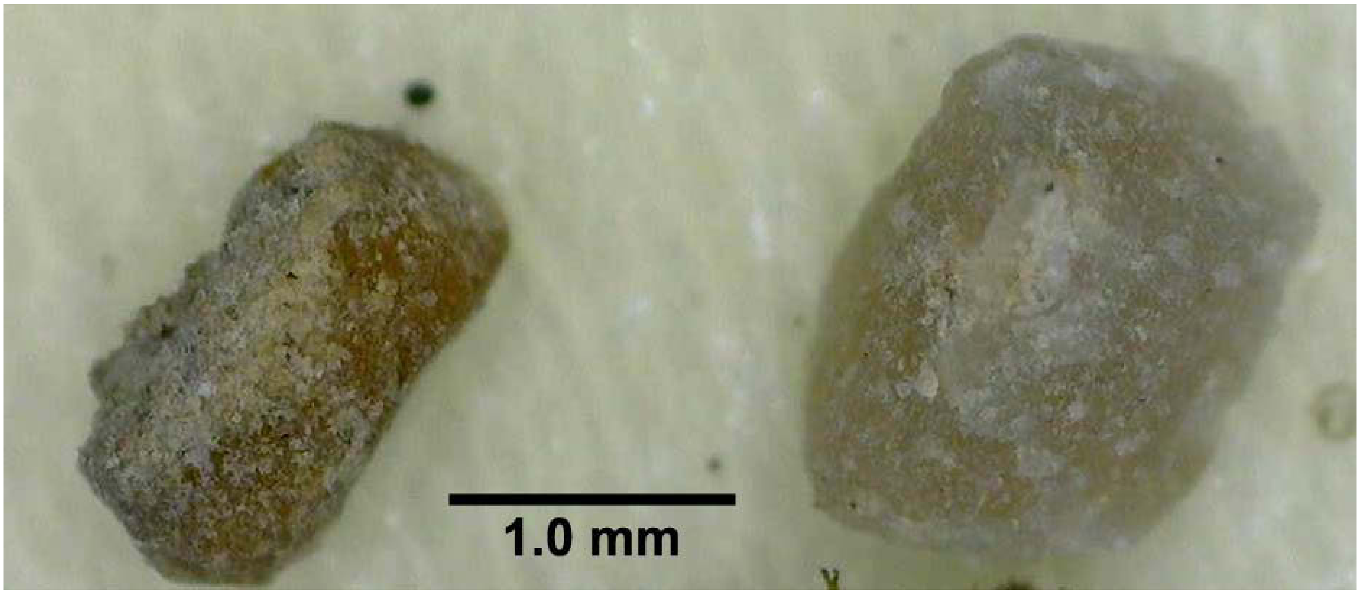


Digital microscope image (wet) – Long Canyon #1 (Map #11), 7030-40 feet, A interval, light gray, microcrystalline dolomite, ostracodal and peloidal grainstone/packstone with modest intercrystalline porosity.

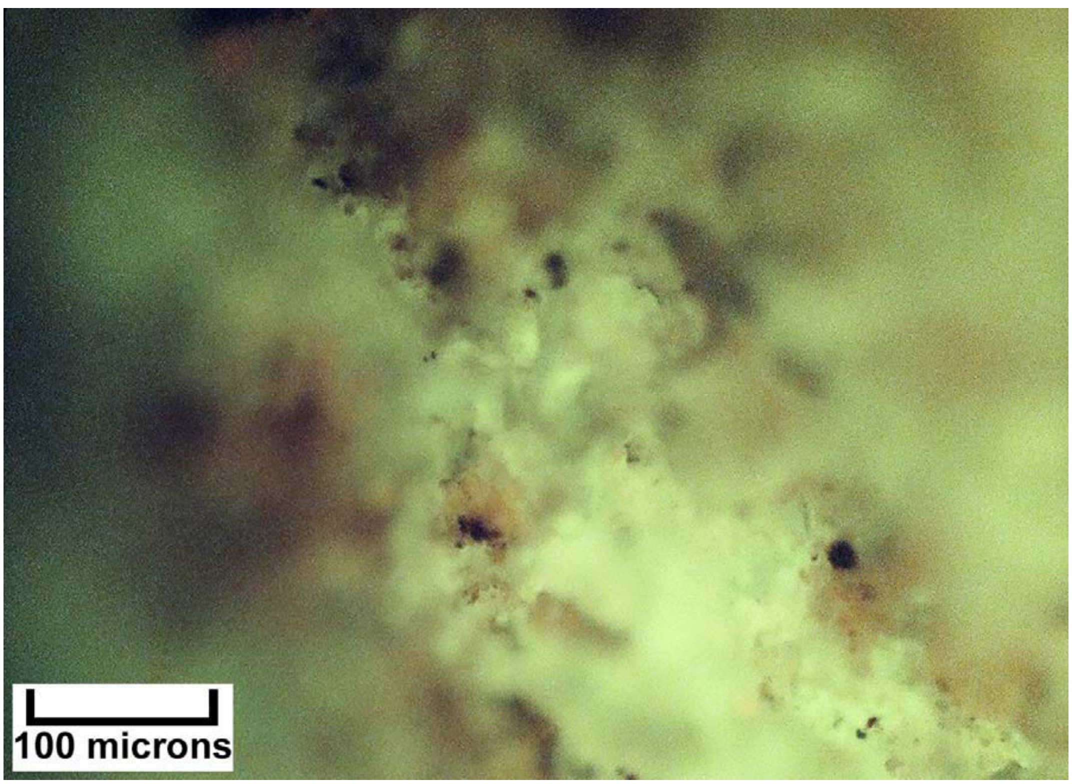
EF photomicrograph – Long Canyon #1 (Map #11), 7030-40 feet, A interval, 2.7 visual epifluorescence rating in medium to coarsely crystalline dolomite with patchy bright fluorescence.

Digital microscope image (dry) – Long Canyon #1 (Map #11), 7060-70 feet, B interval, light gray to medium brown, medium crystalline dolomite composed of ostracods and coated skeletal grains to form a grainstone/packstone, modest intercrystalline porosity present.

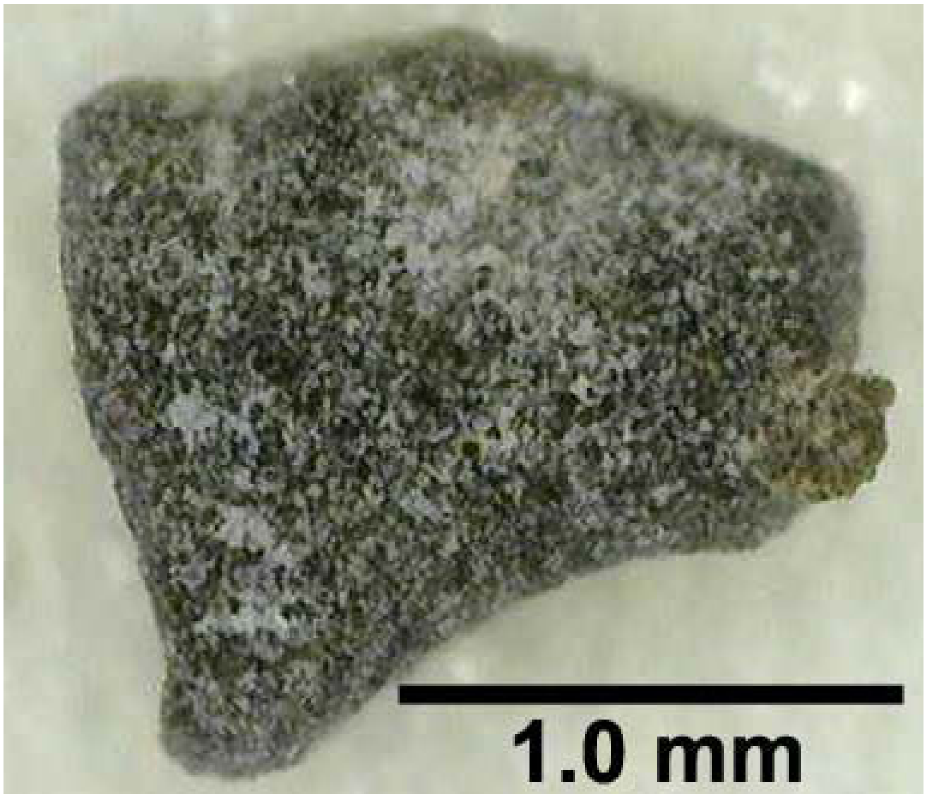
EF photomicrograph – Long Canyon #1 (Map #11), 7060-70 feet, B interval, 2.8 visual epifluorescence rating in medium crystalline dolomite with patchy bright fluorescence.



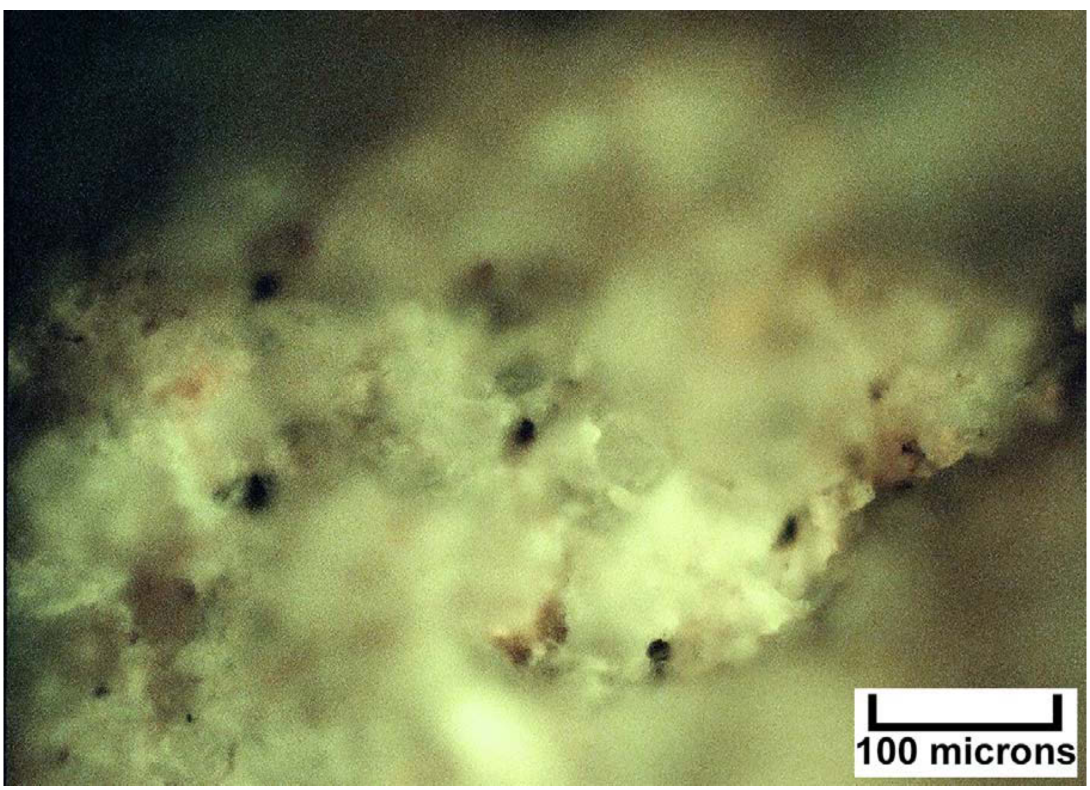
Digital microscope image (dry) – Long Canyon #1 (Map #11), 7070-80 feet, B interval, two cuttings consisting of light gray microcrystalline dolomite, ostracod-rich grainstone.



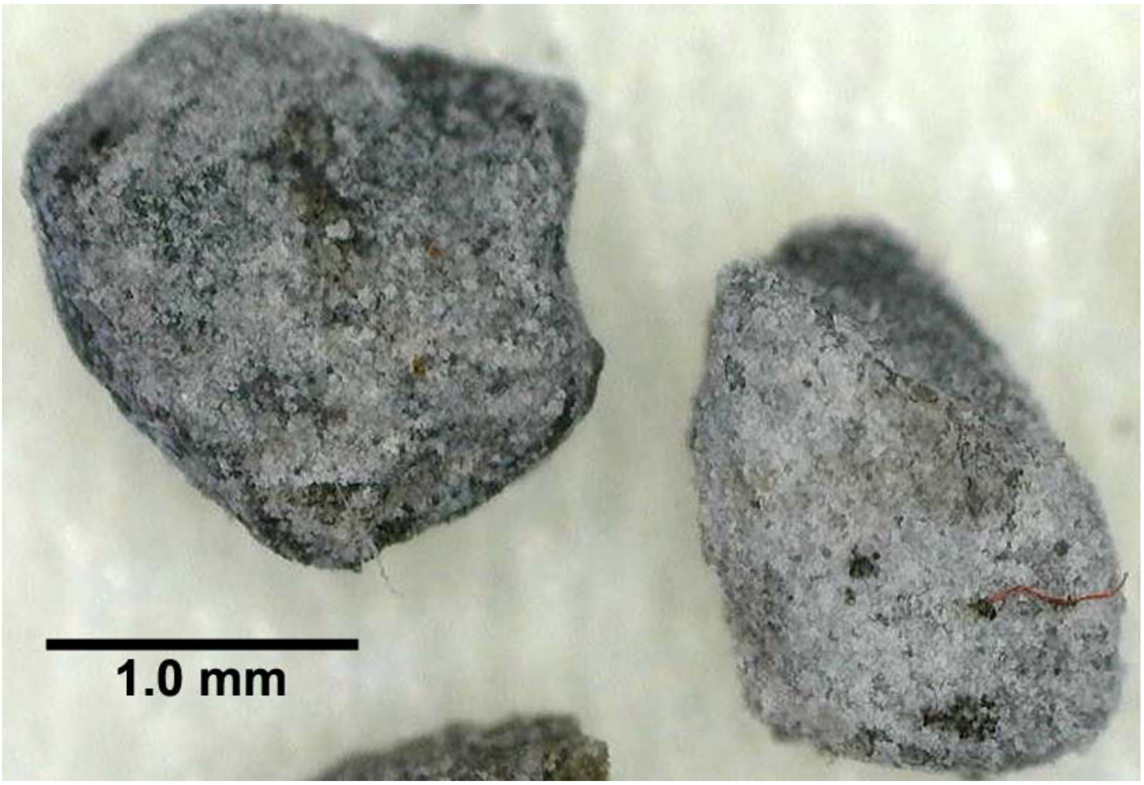
EF photomicrograph – Long Canyon #1 (Map #11), 7070-80 feet, B interval, 2.4 visual epifluorescence rating in skeletal grainstone containing possible ostracods.



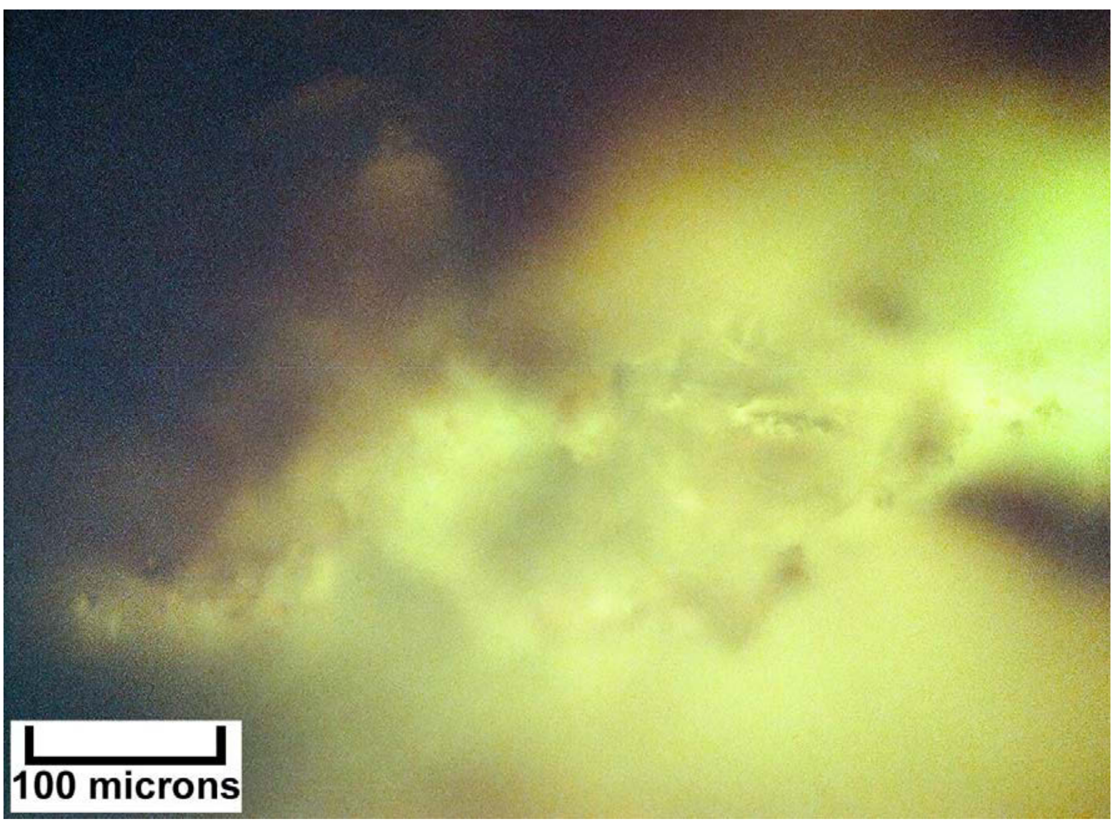
Digital microscope image (dry) – Long Canyon #1 (Map #11), 7095-7100 feet, C interval, dark gray, microcrystalline dolomite consisting of a poorly sorted skeletal grainstone with probable small fenestrate bryozoan fragments.



EF photomicrograph – Long Canyon #1 (Map #11), 7095-7100 feet, C interval, 2.8 visual epifluorescence rating of colonial bryozoan(?); longitudinal view.

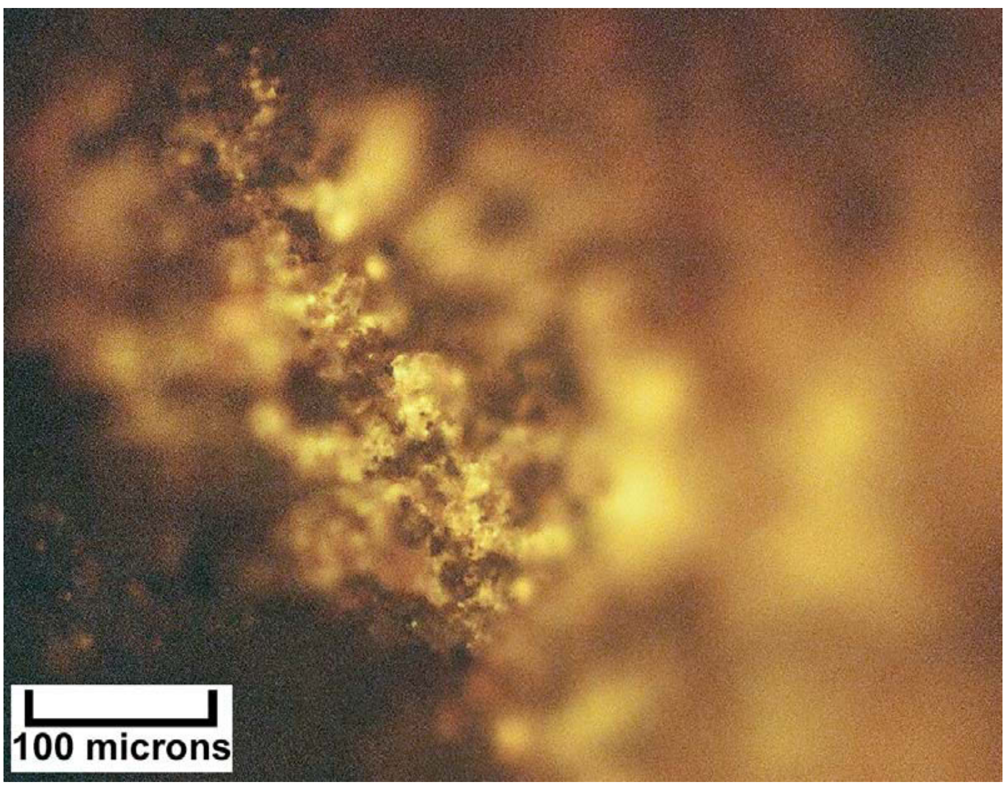


Digital microscope image (dry) – Mineral Canyon #1-14 (Map #12), 7360-70 feet, B interval, two samples showing a light to medium gray, medium crystalline dolomite displaying fair to good intercrystalline porosity partially lined with bitumen; probably composed of skeletal grainstone/packstone containing some ostracods.



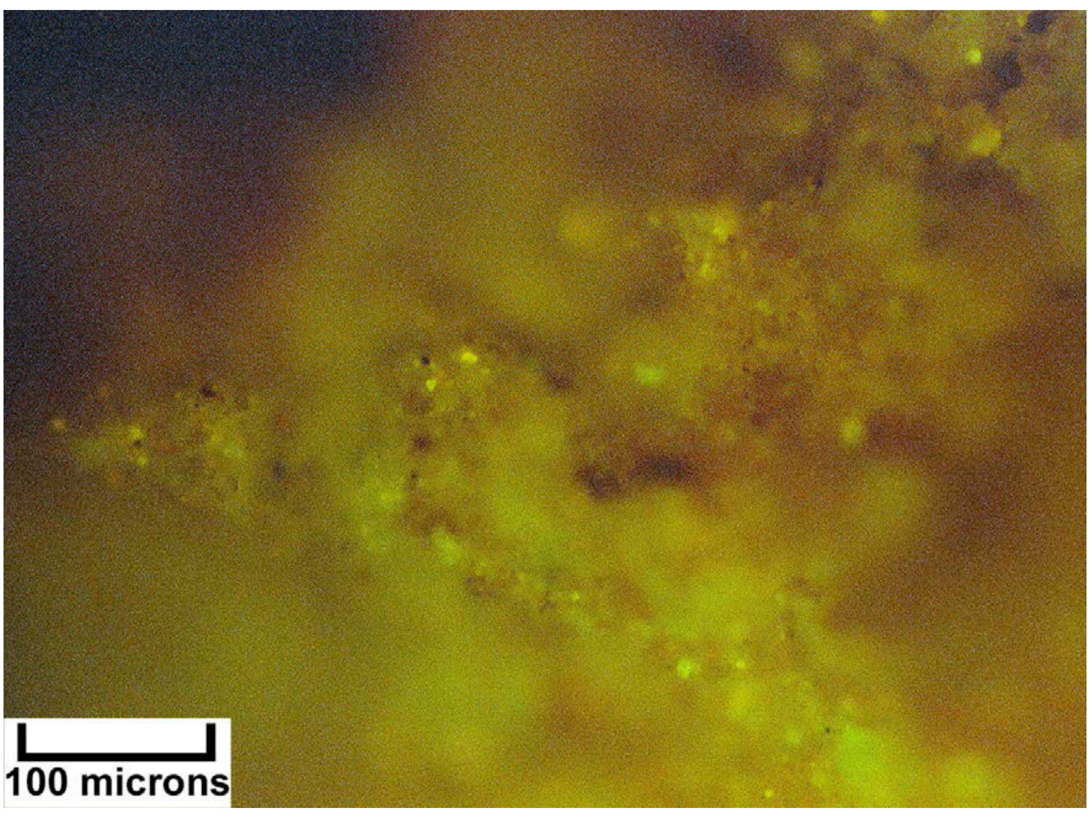
EF photomicrograph – Mineral Canyon #1-14 (Map #12), 7360-70 feet, B interval, 1.7 visual epifluorescence rating in medium crystalline dolomite with modest fluorescence.

Binocular microscope image (wet) – Mineral Canyon #1-14 (Map #12), 7380-90 feet, B interval, hand-picked cuttings showing peloidal dolomite with porosity.

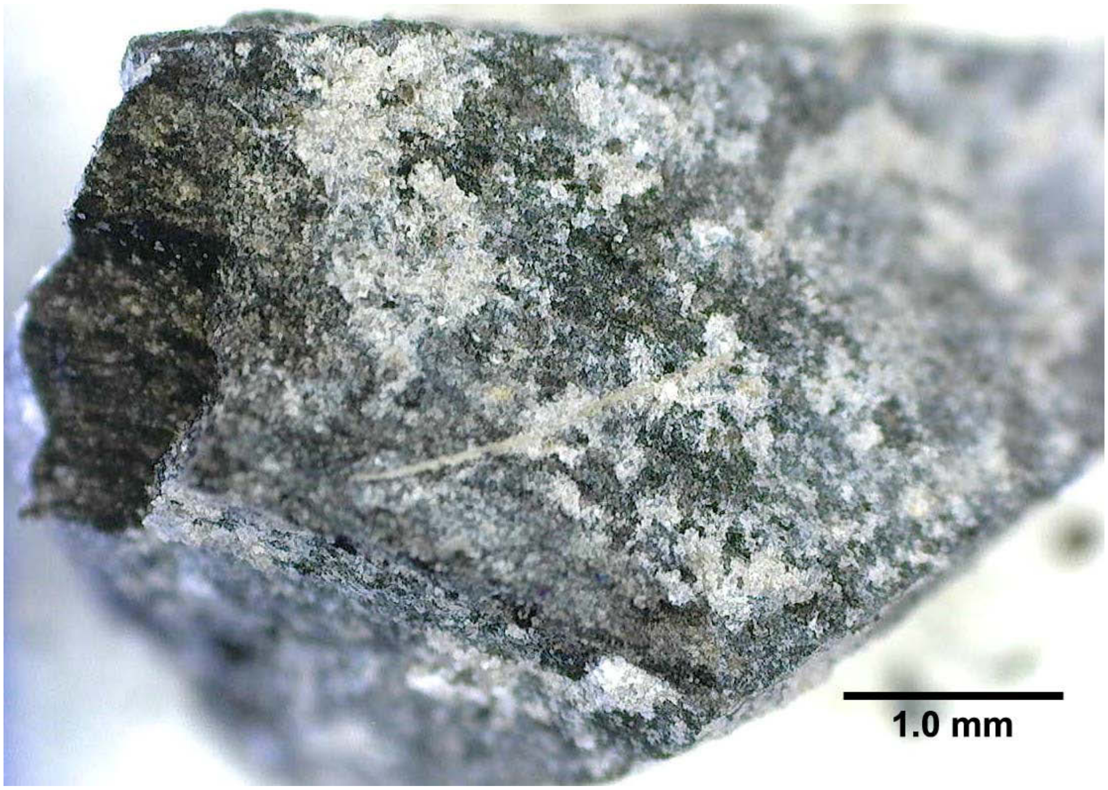


EF photomicrograph – Mineral Canyon #1-14 (Map #12), 7380-90 feet, B interval, 1.5 visual epifluorescence rating in very small samples, highly dolomitic shale with well developed dolomite crystals and microporosity.

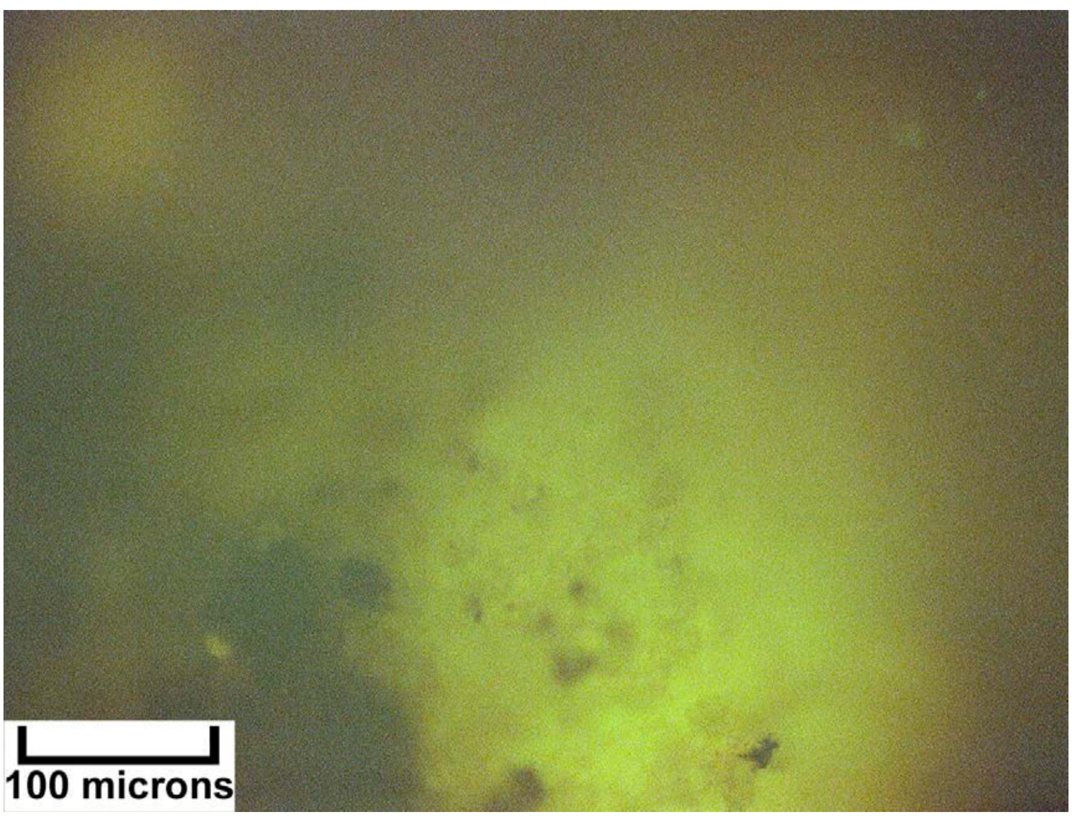
Digital microscope image (dry) – Federal #1-X (Map #13), 6530-40 feet, B interval, medium to dark gray, argillaceous or organic-rich microcrystalline dolomite, possible lumpy microbial structure and anhydrite-filled microstructures.



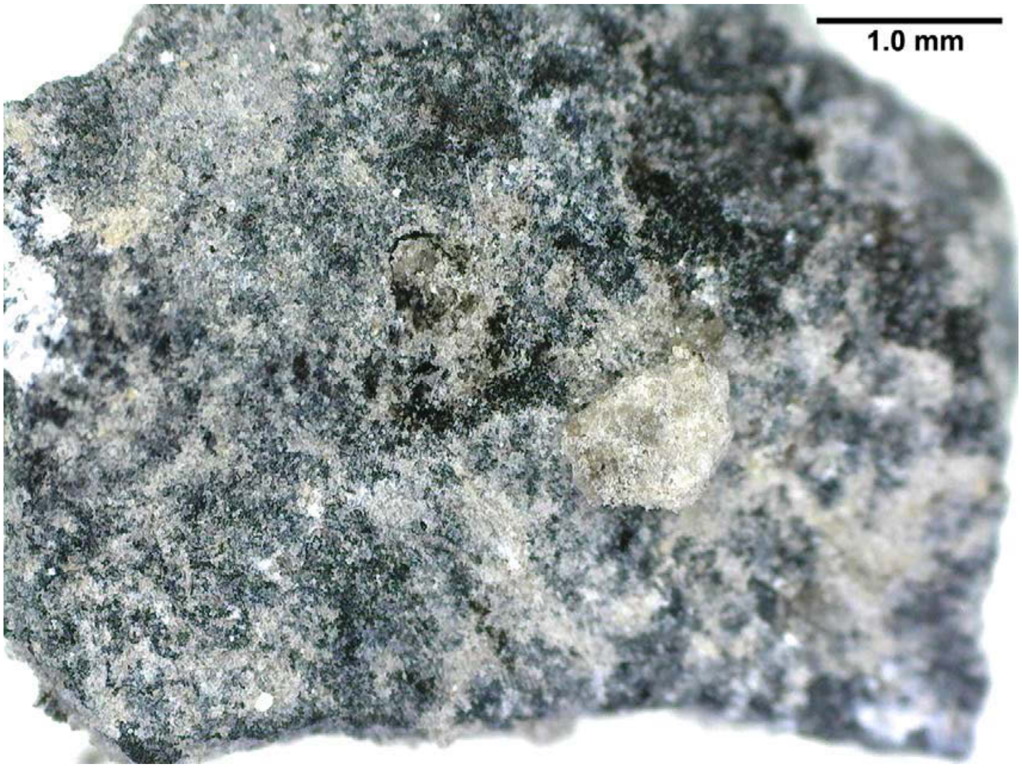
EF photomicrograph – Federal #1-X (Map #13), 6530-40 feet, B interval, 2.1 visual epifluorescence rating in microfractured dolomitic shale.



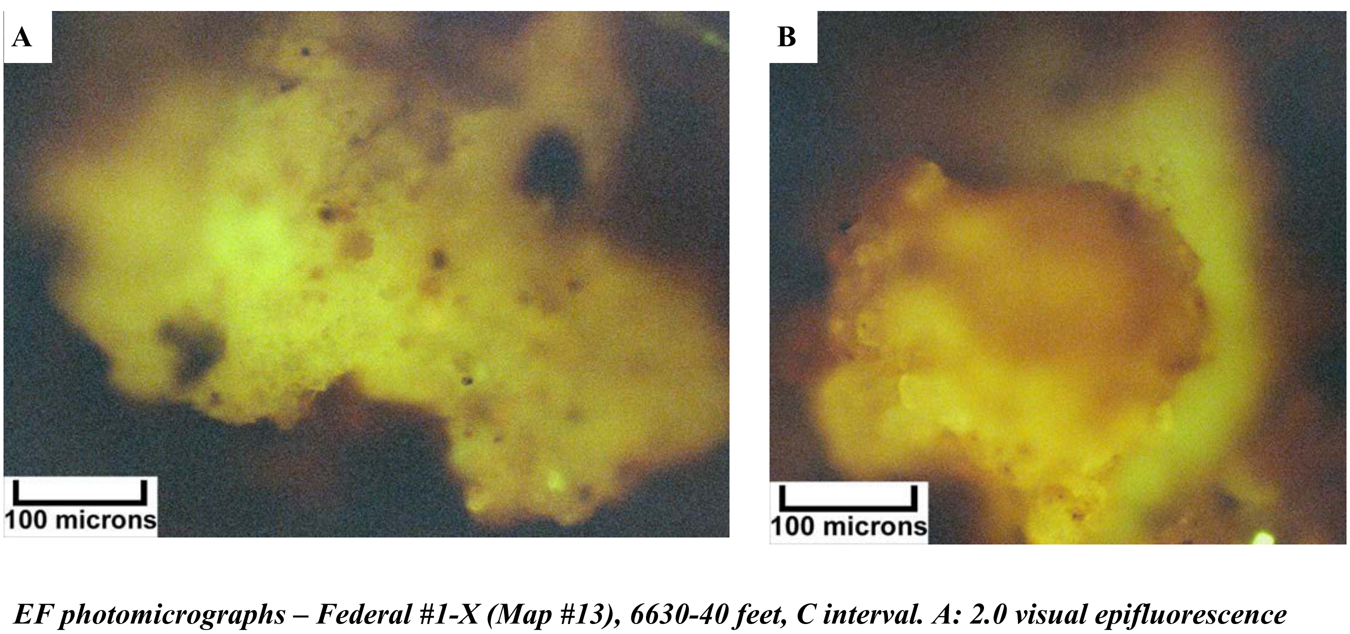
Digital microscope image (dry) – Federal #1-X (Map #13), 6620-30 feet, C interval, dark gray laminated dolomitic shale with patches of white dolomite rhombs, no visible porosity.



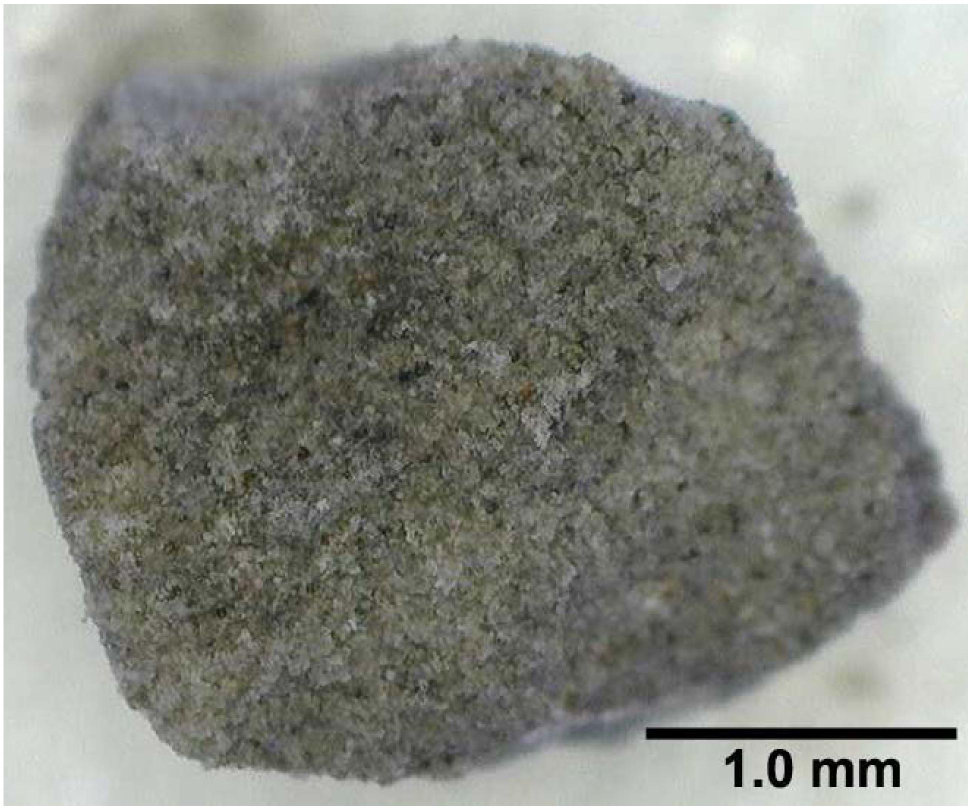
EF photomicrograph – Federal #1-X (Map #13), 6620-30 feet, C interval, 2.1 visual epifluorescence rating in aggregates of rhombic dolomite in silty and slightly dolomitic shale.



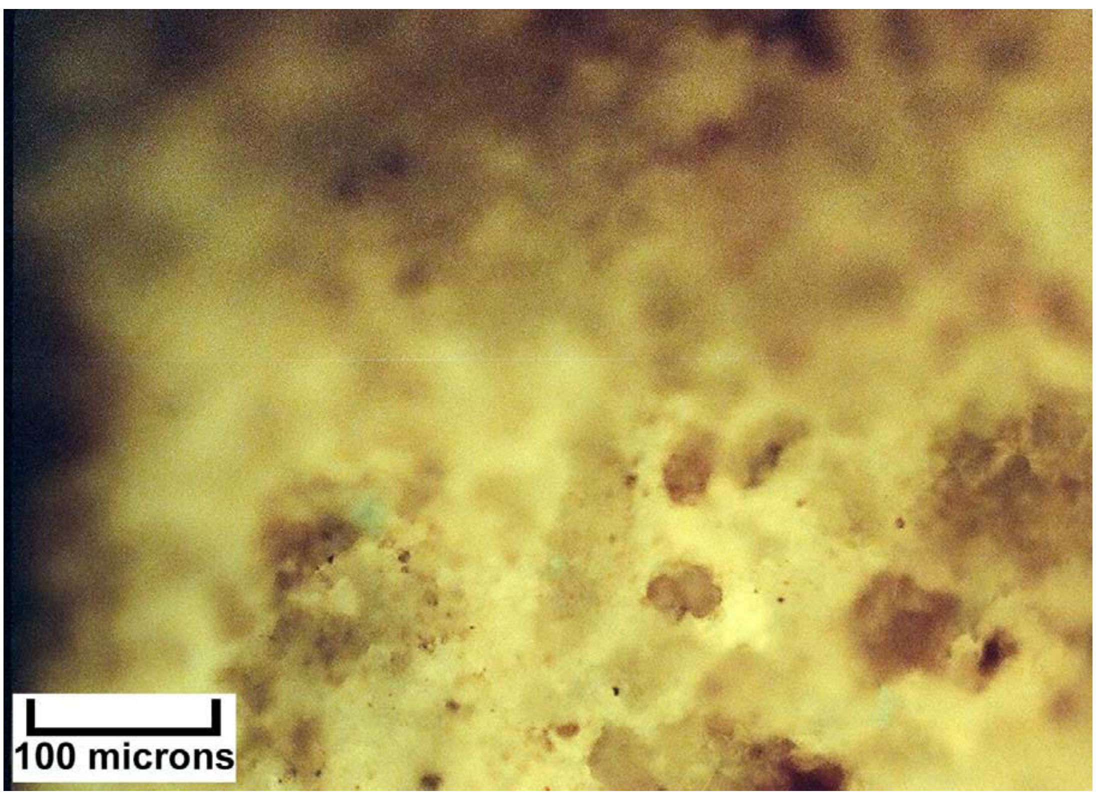
Digital microscope image (dry) – Federal #1-X (Map #13), 6630-40 feet, C interval, light to dark gray, finely crystalline argillaceous dolomite with isolated patches of light gray, medium crystalline dolomite.



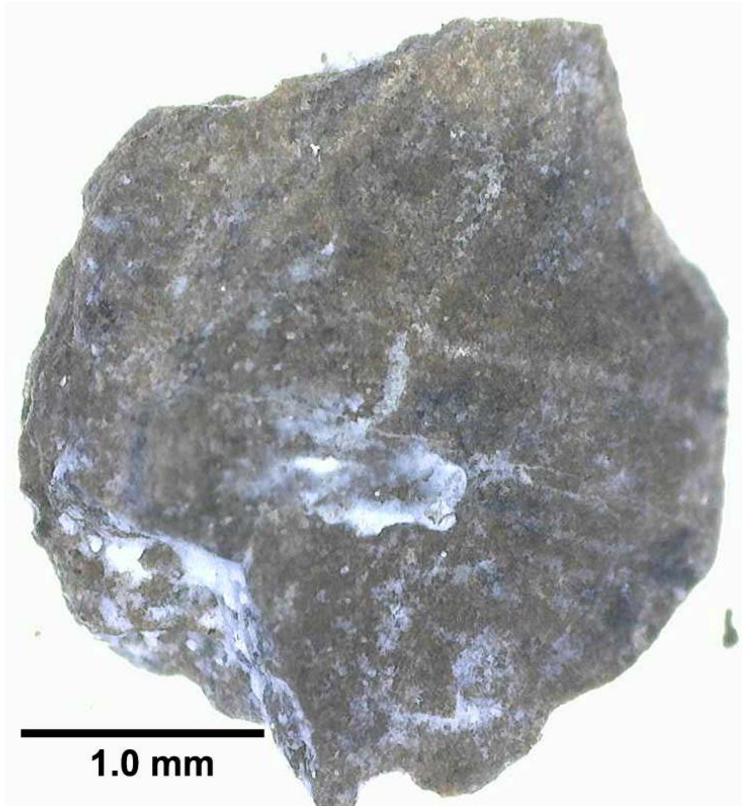
EF photomicrographs – Federal #1-X (Map #13), 6630-40 feet, C interval. A: 2.0 visual epifluorescence rating in highly dolomitic shale with possible anhydrite clusters. B: 2.8 visual epifluorescence rating in anhydritic dolomite.



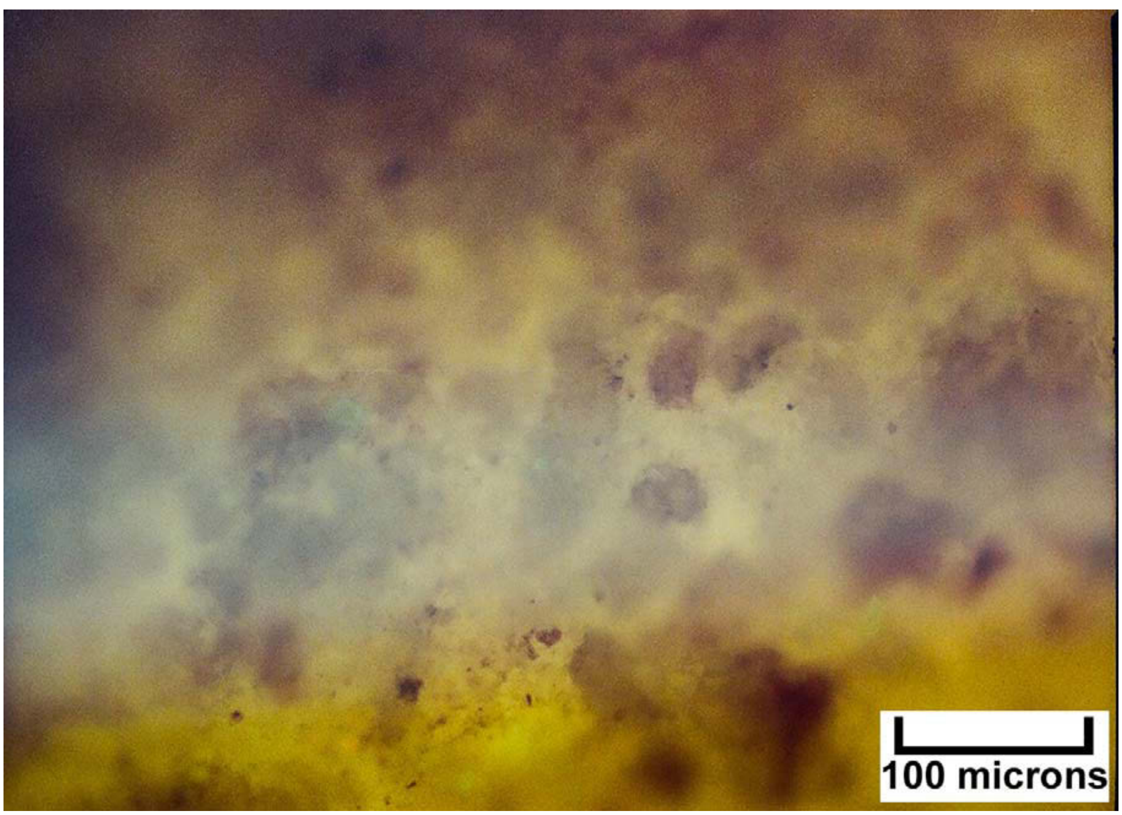
Digital microscope image (dry) – Featherstone #9-1 (Map #14), 5800-10 feet, A interval, medium gray, silty to slightly argillaceous dolomite, fine to medium crystalline with modest intercrystalline porosity.



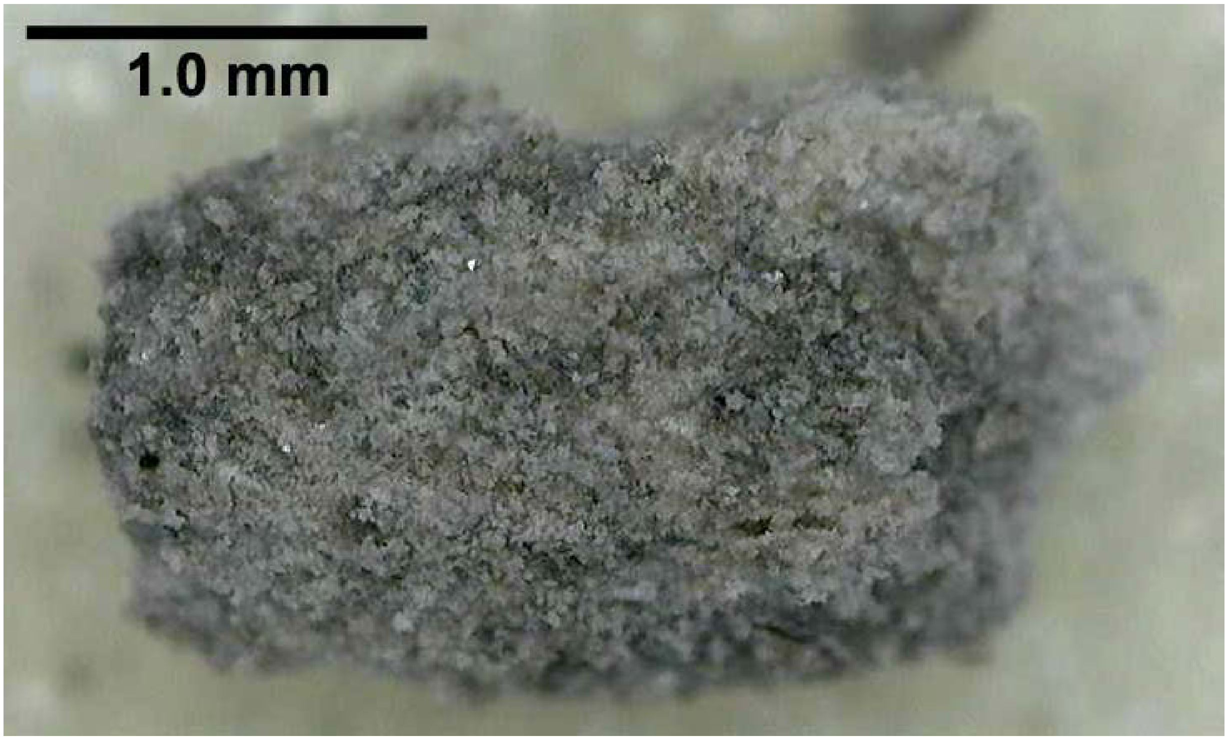
EF photomicrograph – Featherstone #9-1 (Map #14), 5800-10 feet, A interval, 2.3 visual epifluorescence rating in porous dolomitic siltstone.



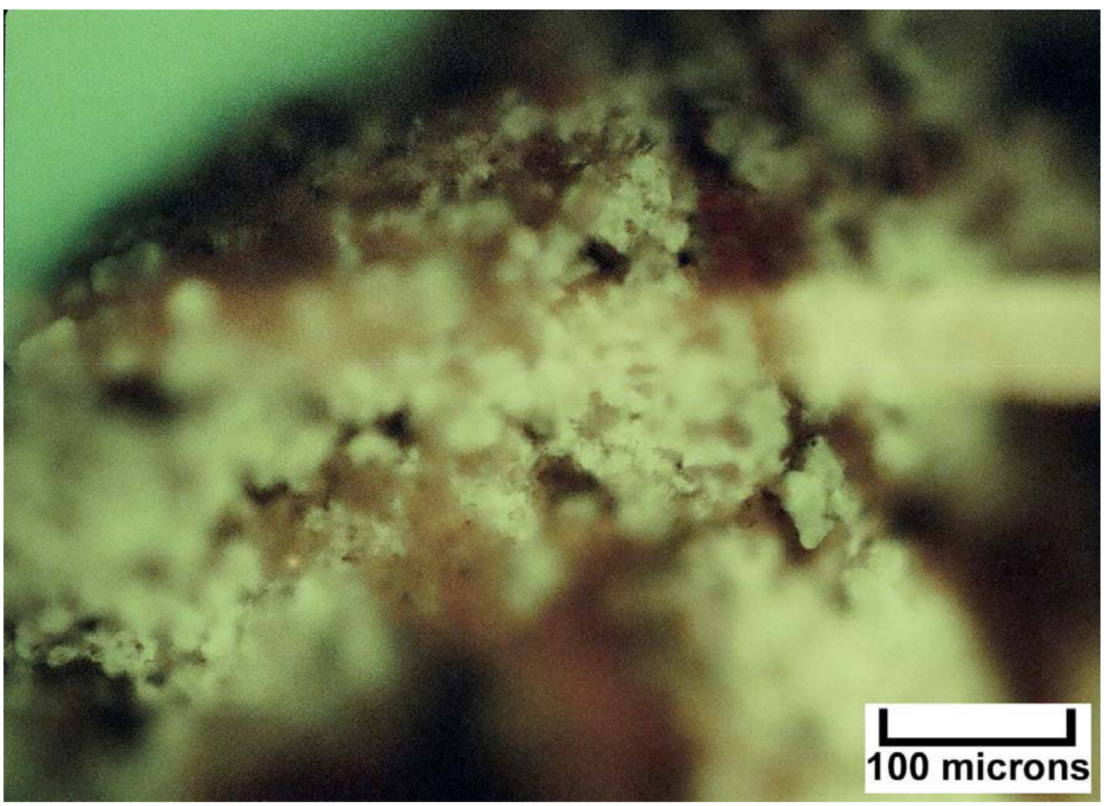
Digital microscope image (wet) – Featherstone #9-1 (Map #14), 5810-20 feet, B interval, medium brown-gray microcrystalline dolomite, thin bedded with a mixed skeletal and microbial composition, possibly packstone or bindstone fabric; no visible porosity.



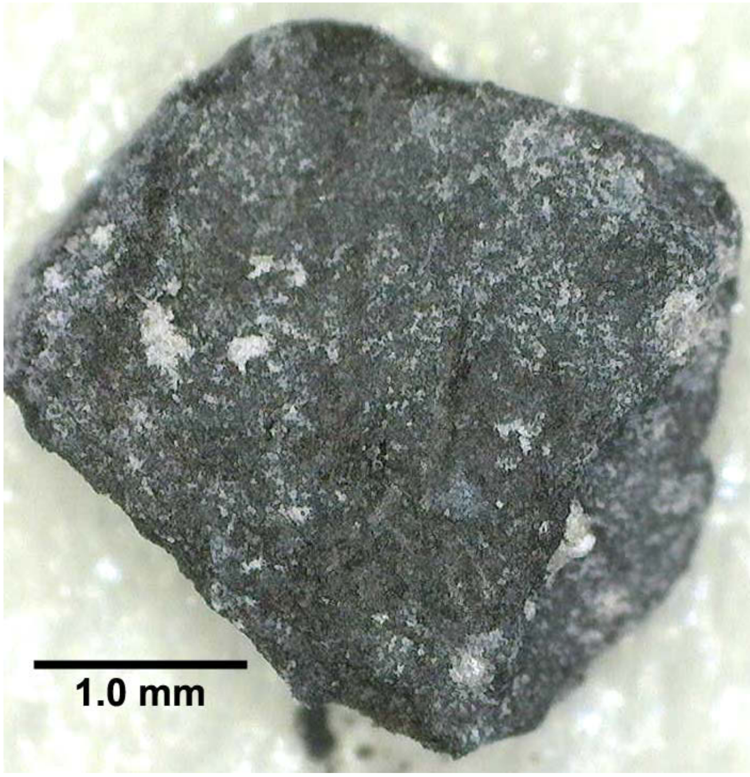
EF photomicrograph – Featherstone #9-1 (Map #14), 5810-20 feet, B interval, 2.3 visual epifluorescence rating in partially dolomitized fossiliferous siltstone, possibly bryozoan.



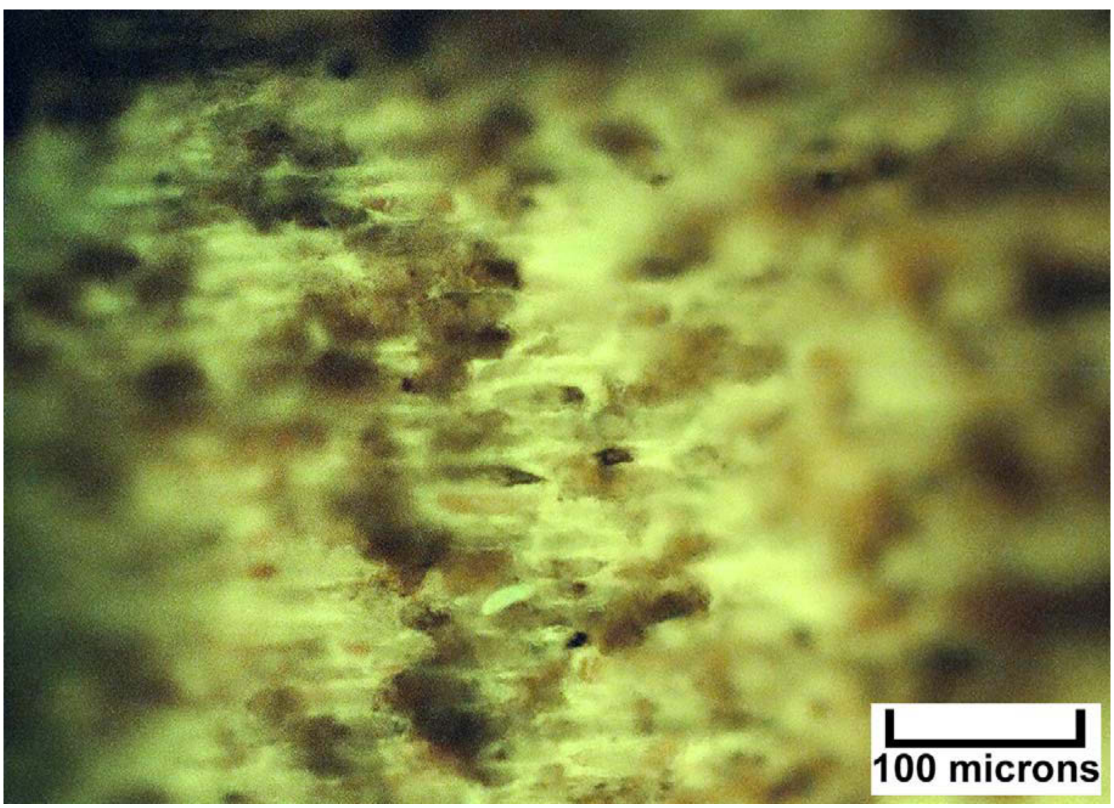
Digital microscope image (dry) – Featherstone #9-1 (Map #14), 5830-40 feet, B interval, white to medium gray dolomite, fine to medium crystalline with visible intercrystalline pore spaces, probable skeletal-peloidal packstone/wackestone.



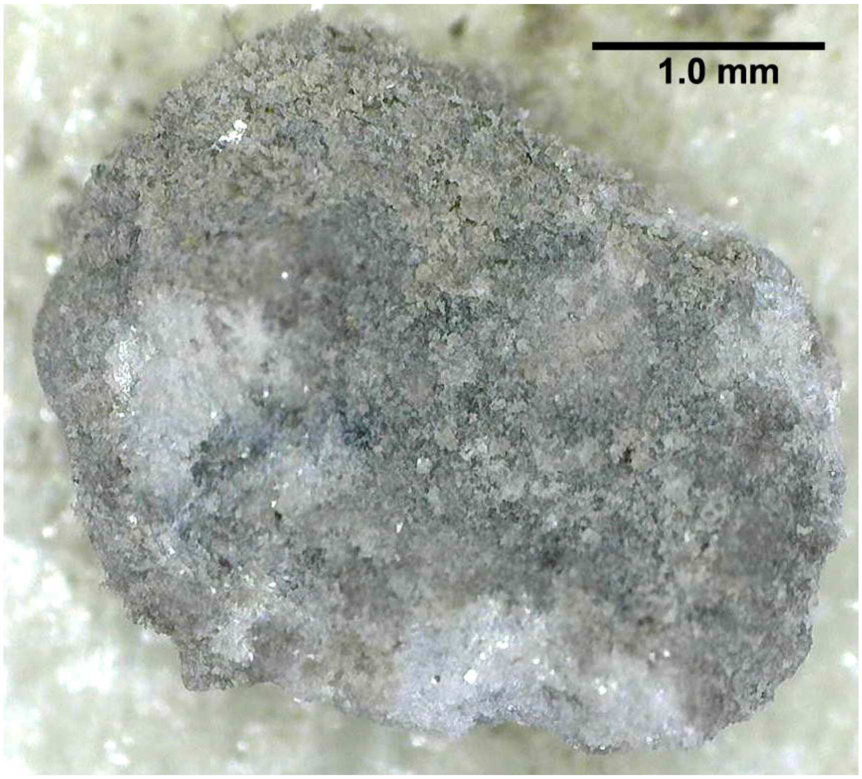
EF photomicrograph – Featherstone #9-1 (Map #14), 5830-40 feet, B interval, 2.5 visual epifluorescence rating in very silty dolomite with fine to medium dolomite crystal aggregates.



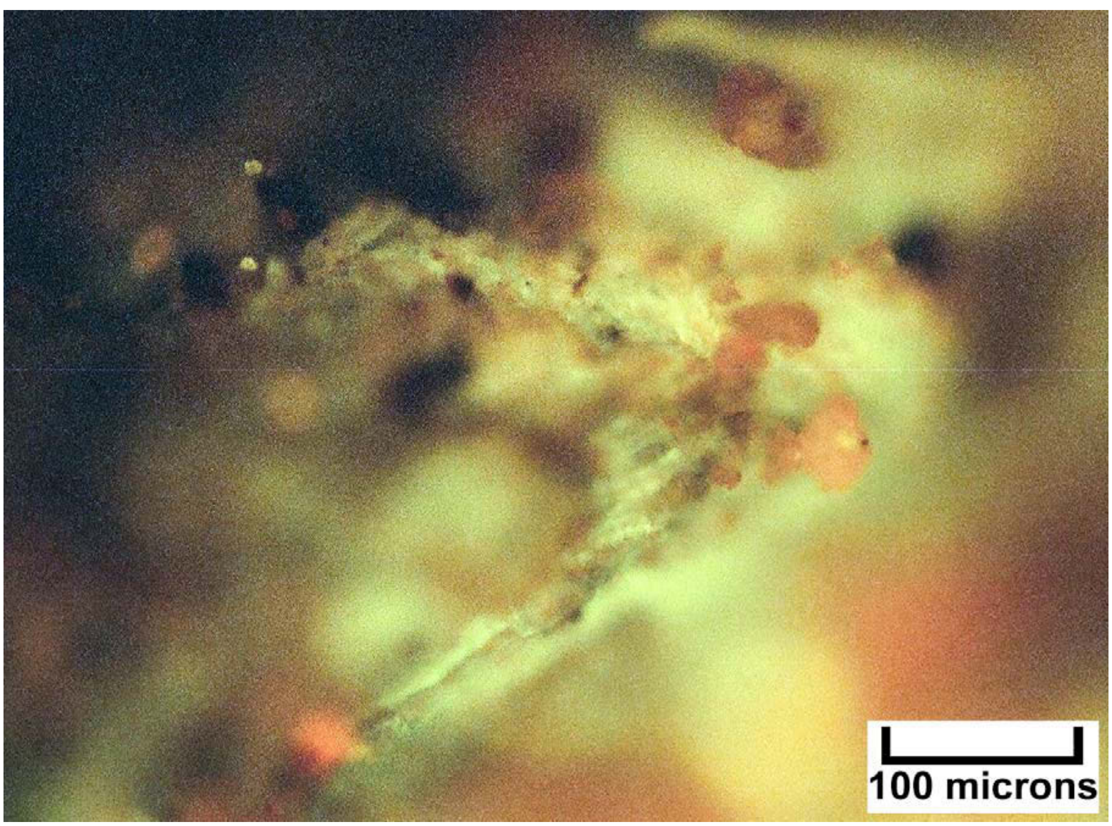
Digital microscope image (dry) – Featherstone #9-1 (Map #14), 5840-50 feet, B interval, medium gray to black, slightly dolomitic shale to argillaceous dolomite, occasional isolated patches of medium crystalline dolomite.



EF photomicrograph – Featherstone #9-1 (Map #14), 5840-50 feet, B interval, 2.9 visual epifluorescence rating in dolomitic tubular microbialite matrix with modest intercrystalline and within-tubule porosity.

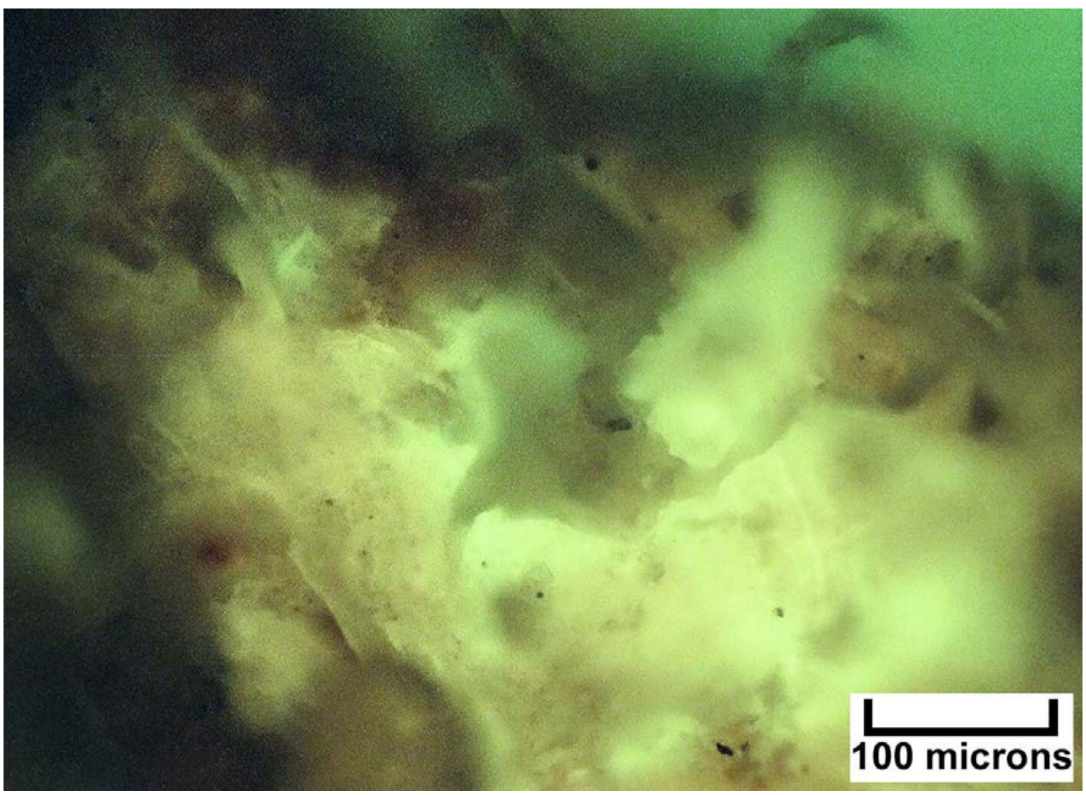


Digital microscope image (dry) – Featherstone #9-1 (Map #14), 5850-60 feet, B interval, light to medium gray dolomite, fine to medium crystalline, skeletal wackestone/packstone; fair to good intercrystalline porosity despite patches of anhydrite replacement.

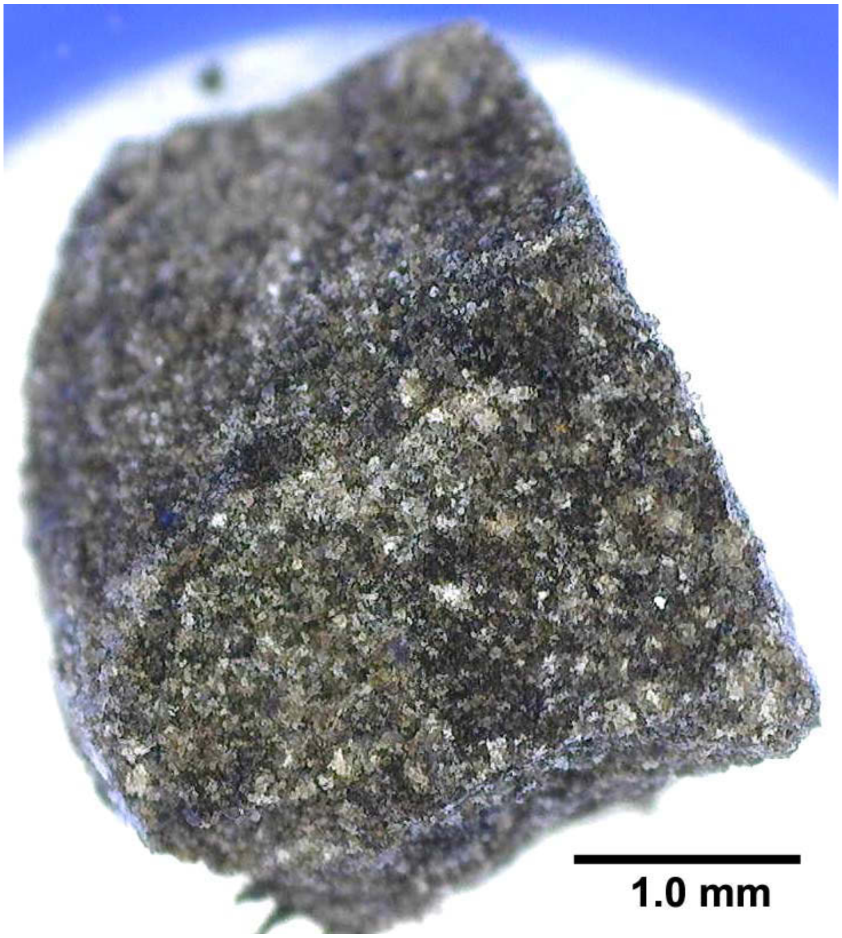


EF photomicrograph – Featherstone #9-1 (Map #14), 5850-60 feet, C interval, 2.7 visual epifluorescence rating in cluster of dolomite near a styolite seam or microfracture.

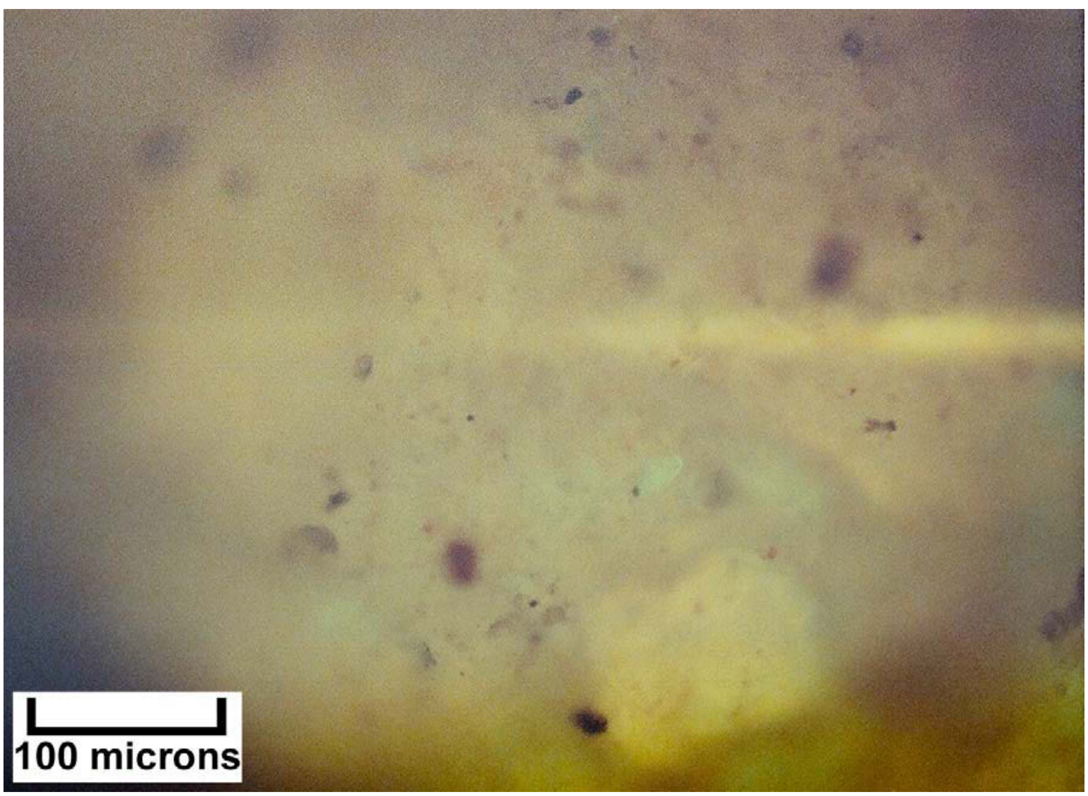
Digital microscope image (dry) – Featherstone #9-1 (Map #14), 5860-70 feet, B interval, light to medium gray, fine to medium crystalline dolomite, slightly argillaceous, fine-grained skeletal wackestone/ packstone with modest intercrystalline pore space.



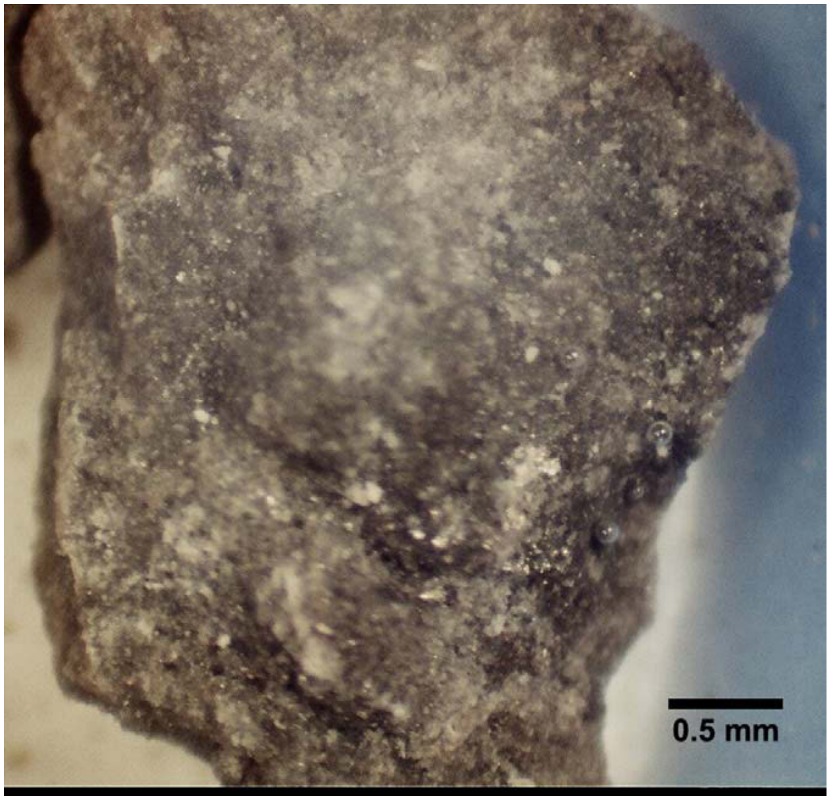
EF photomicrograph – Featherstone #9-1 (Map #14), 5860-70 feet, B interval, 2.9 visual epifluorescence rating in medium to coarse crystalline dolomite with possible fossil debris and visible pore spaces.



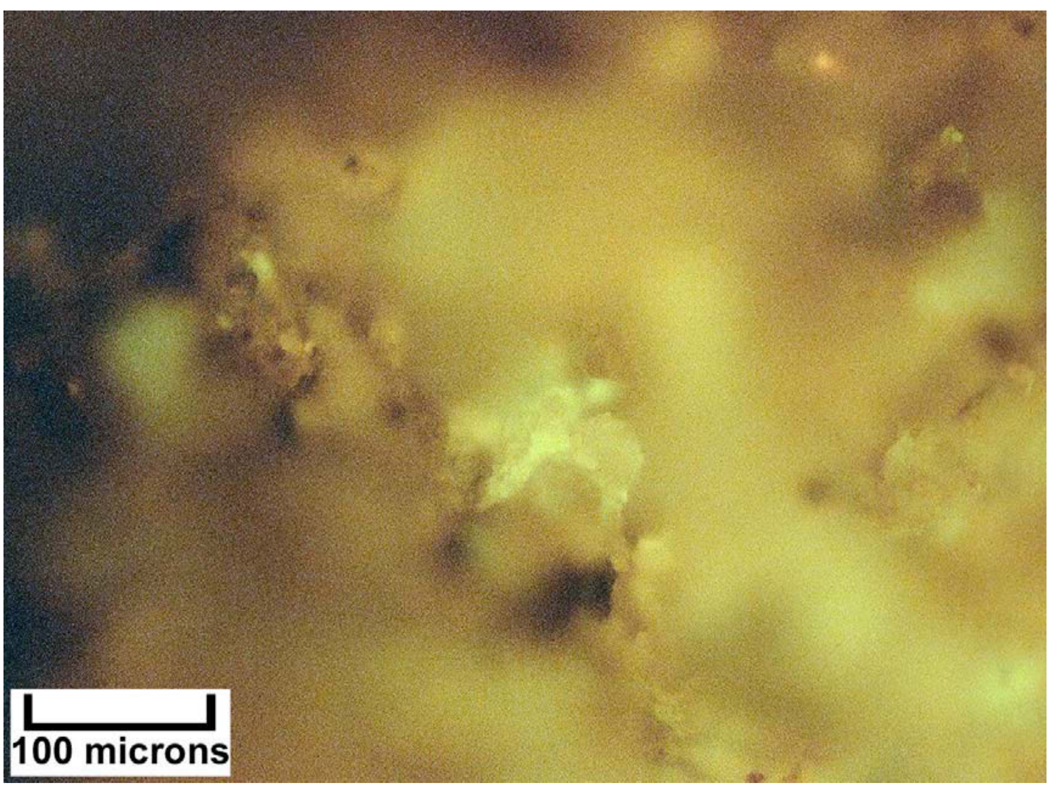
Digital microscope image (dry) – Featherstone #9-1 (Map #14), 5870-80 feet, B interval, medium to dark gray, argillaceous dolomite with fine to medium crystal size, peloidal-skeletal wackestone; no visible porosity.



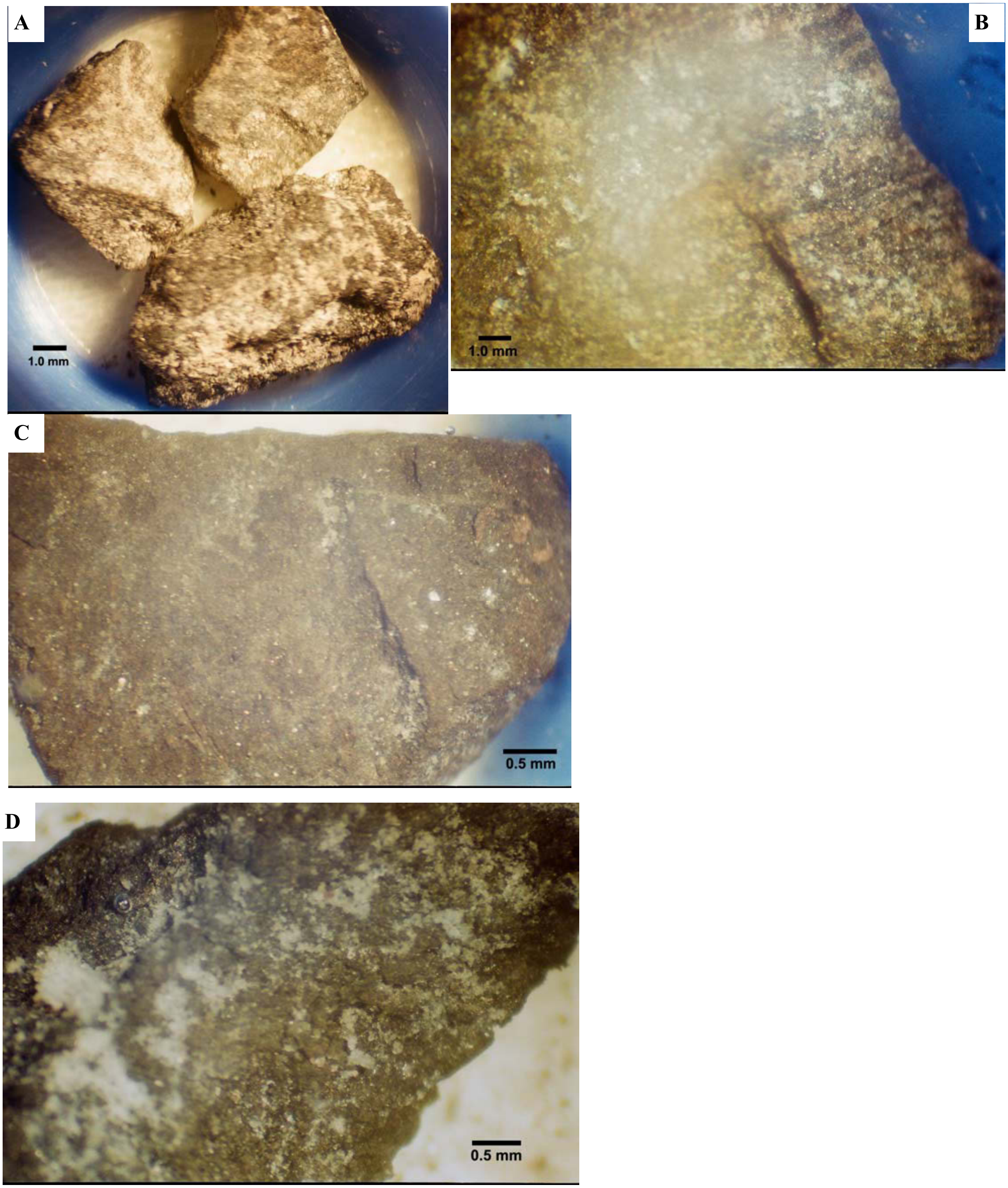
EF photomicrograph – Featherstone #9-1 (Map #14), 5870-80 feet, B interval, 2.3 visual epifluorescence rating in silty dolomitic wackestone.



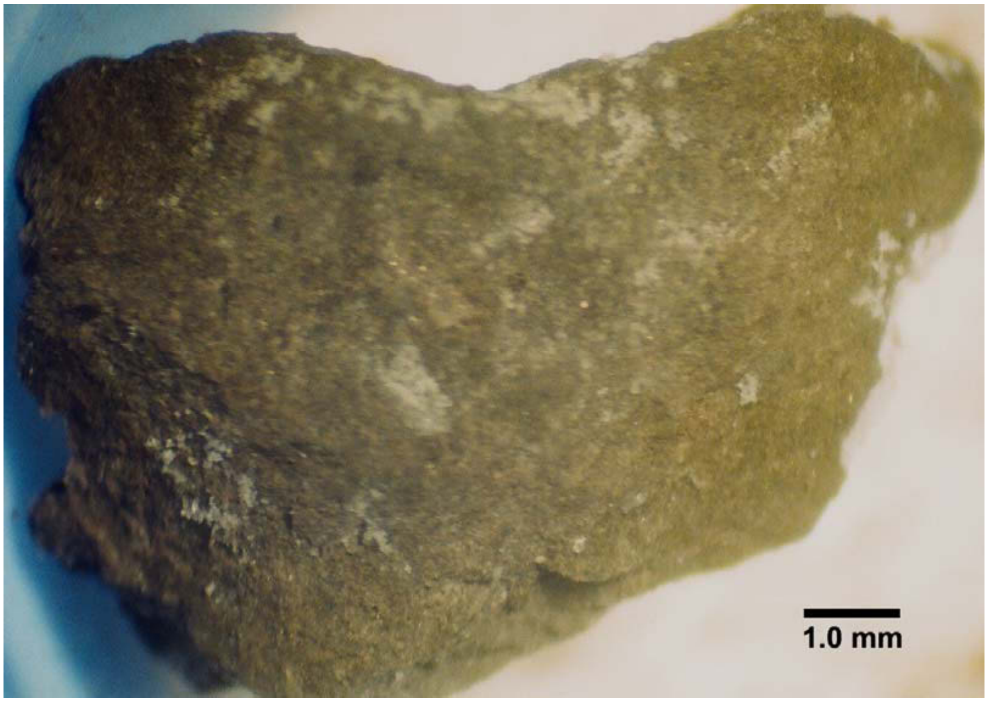
Binocular microscope image (wet and etched) – Bridger Jack U #3 (Map #15), 5920-30 feet, B interval, dark gray peloidal dolomite with pyrite.



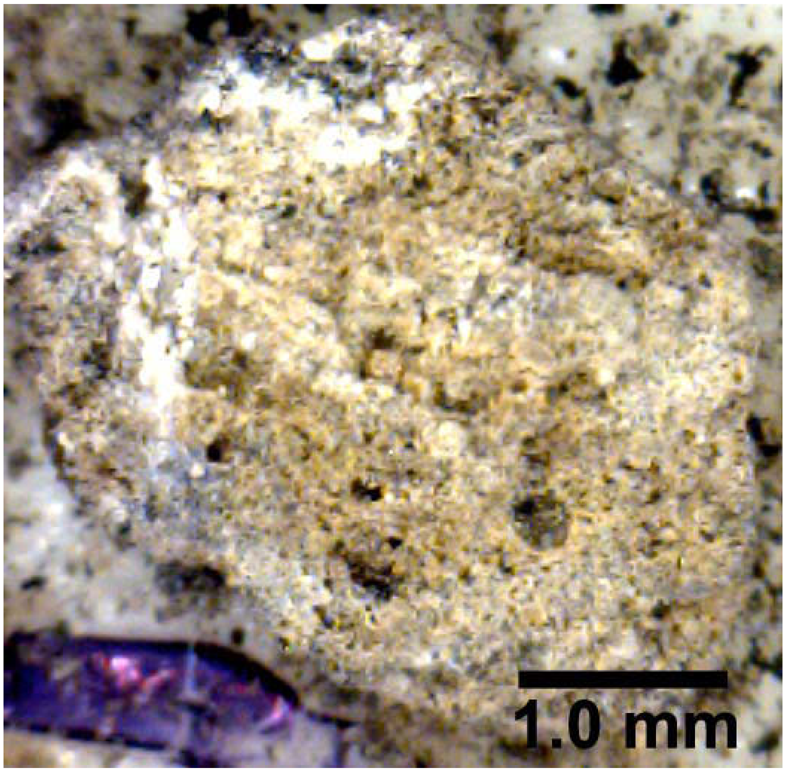
EF photomicrograph – West Bridger Jack U #3 (Map #15), 5920-30 feet, B interval, 1.2 visual epifluorescence rating in dolomitic shale.



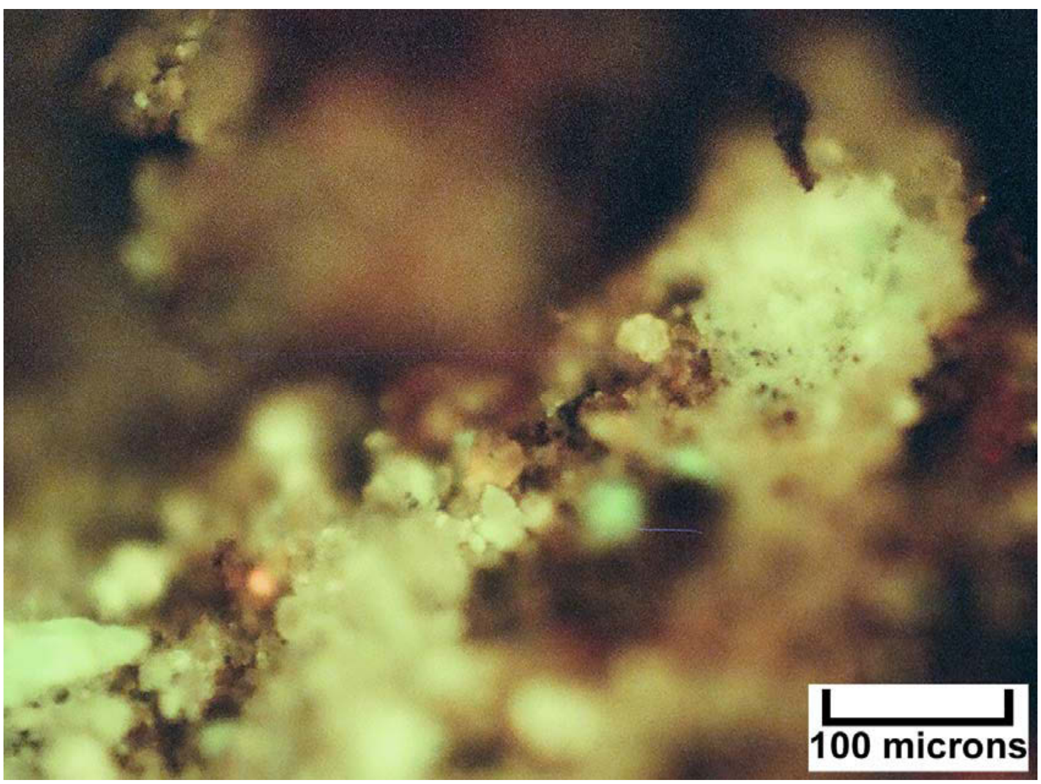
Binocular microscope images – Bridger Jack U #3 (Map #15), 5940-50 feet, C interval. A: (dry) three representative cuttings. B: (wet) close up of microporous microbialite showing stromatolitic microlaminae. C: (wet) peloidal dolomite with hints of parallel microfractures. D: (wet) peloidal black shale with white dolomite and anhydrite.



Binocular microscope image (wet) – Bridger Jack U #3 (Map #15), 5960-70 feet, C interval, representative dolomitic sample showing oncolites/pisolites(?).

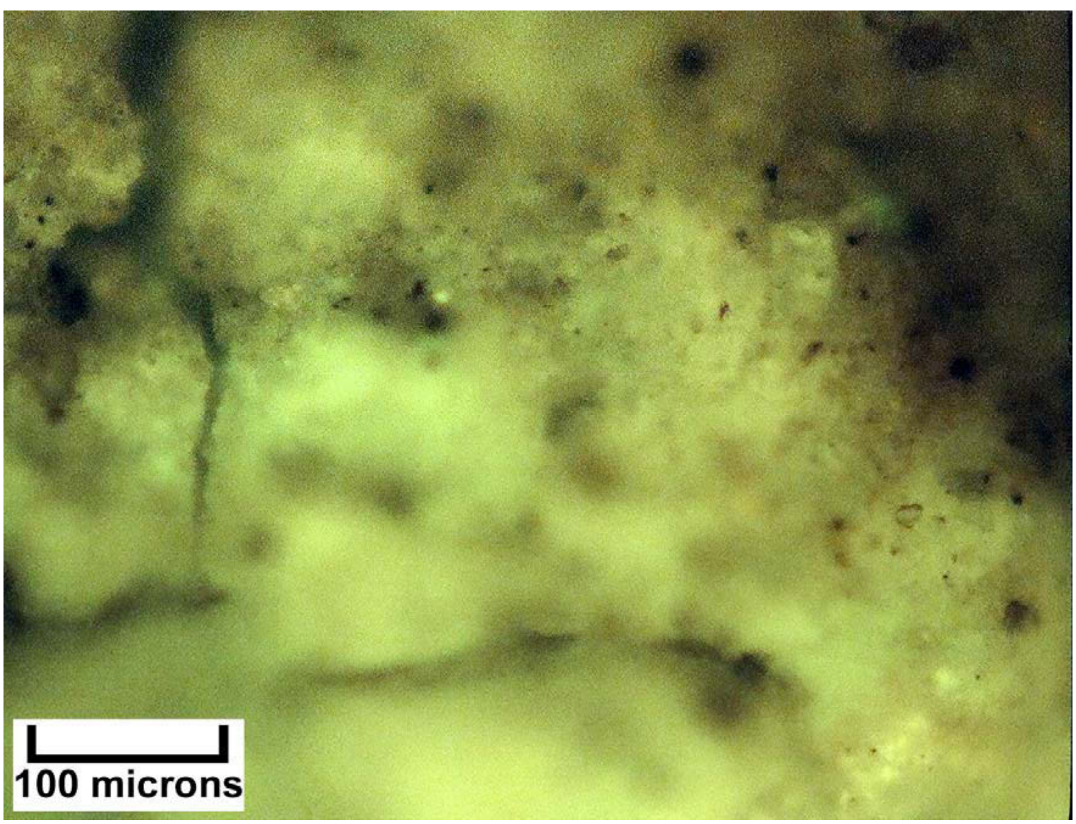


Digital microscope image (dry) – Cane Creek State #1-36 (Map #16), 7000-10 feet, A interval, very porous microbial dolomite. Note the visible pores between the constructional microbialite fabric network as well as the light brown oil staining.

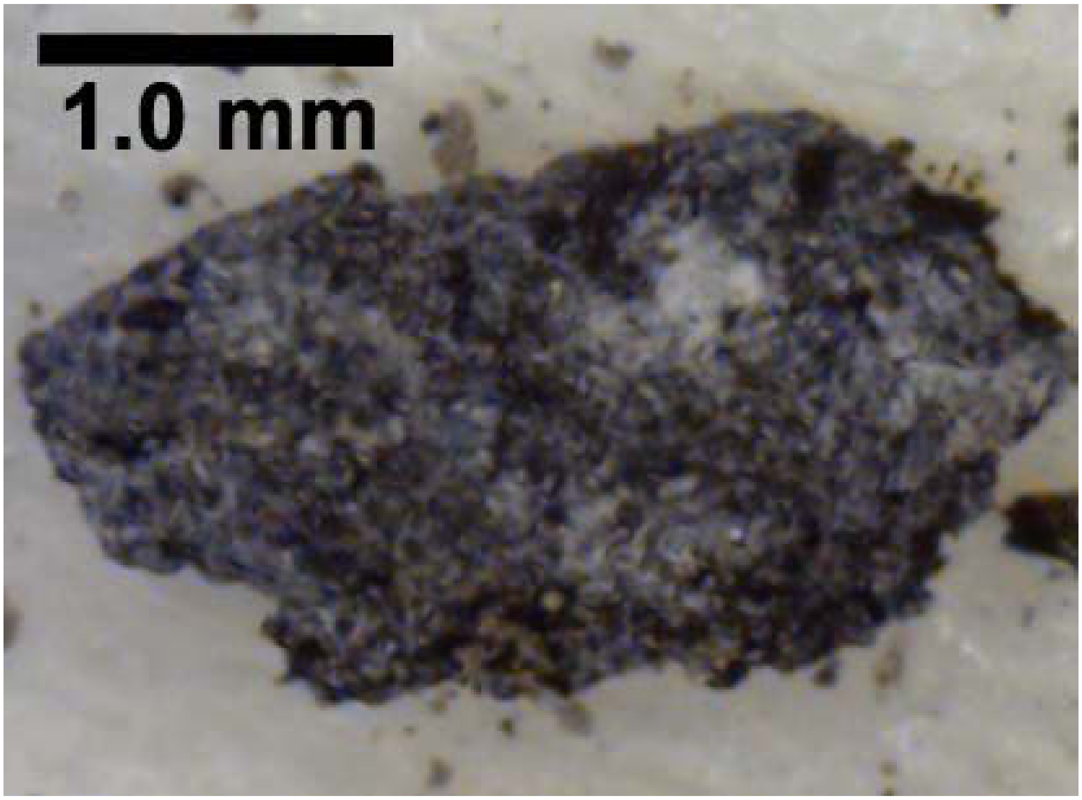


EF photomicrograph – Cane Creek State #1-36 (Map #16), 7000-10 feet, A interval, 2.8 visual epifluorescence rating in dolomitized microbialite with fluorescence in pore space surrounding dolomite crystals and microbial filaments.

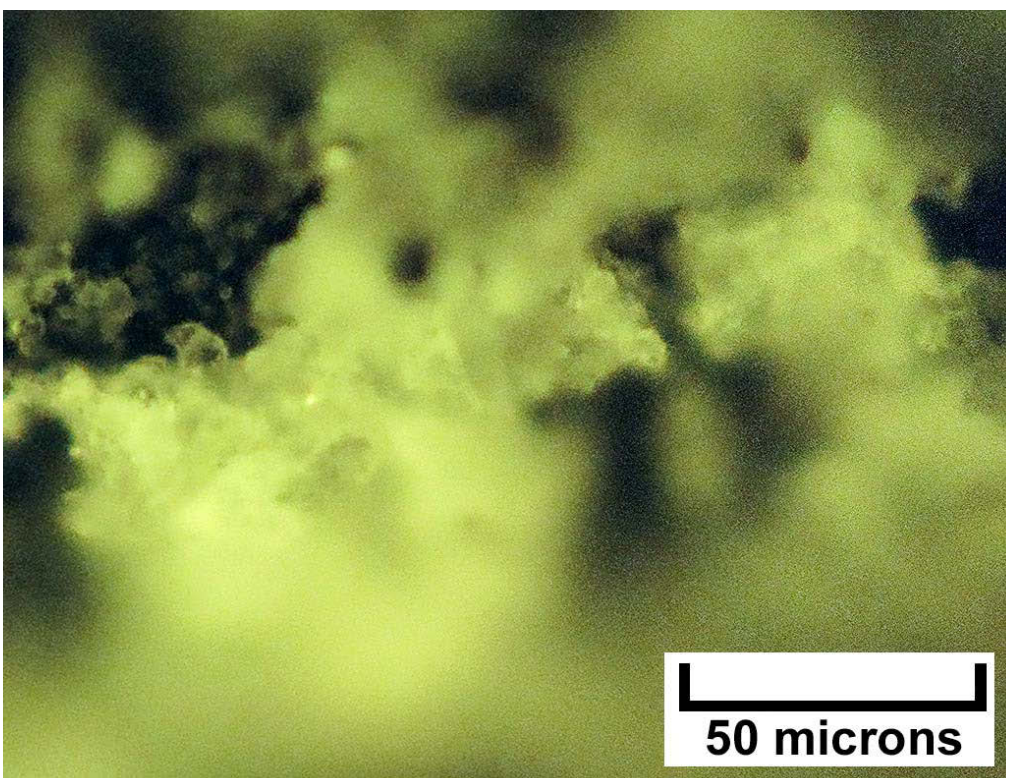
Digital microscope image (dry) – Cane Creek State #1-36 (Map #16), 7010-20 feet, A interval, silty dolomite with visible pores between the dolomite crystals. Black bitumen lines some of the pores.



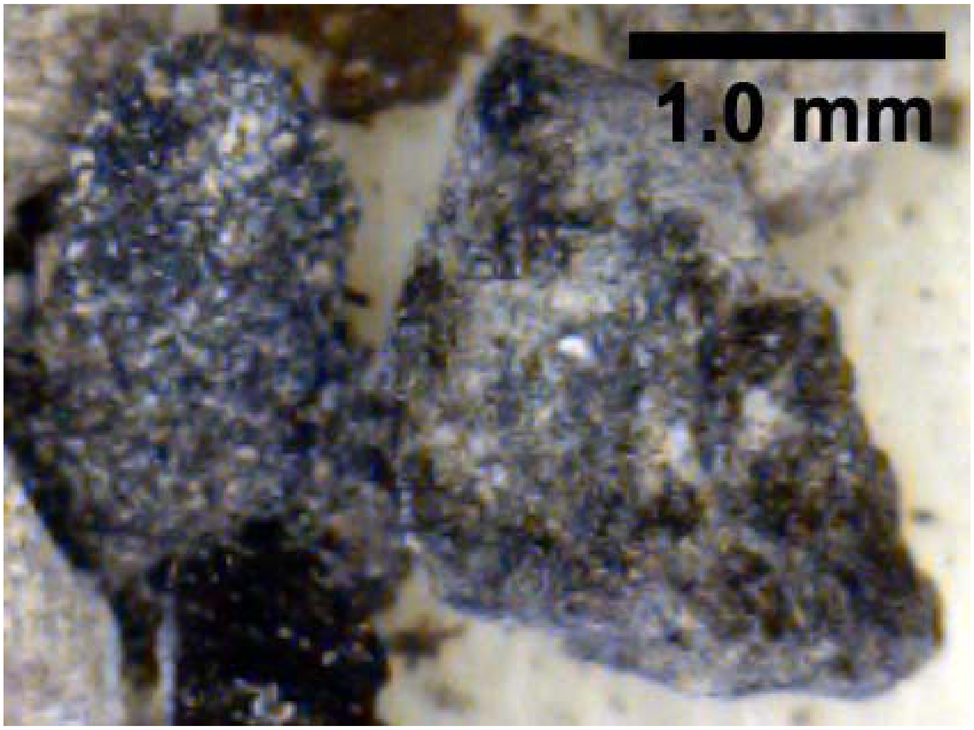
EF photomicrograph – Cane Creek State #1-36 (Map #16), 7010-20 feet, A interval, 2.9 visual epifluorescence rating in slightly dolomitic siltstone with excellent fluorescence between detrital silt grains and dolomite crystals.



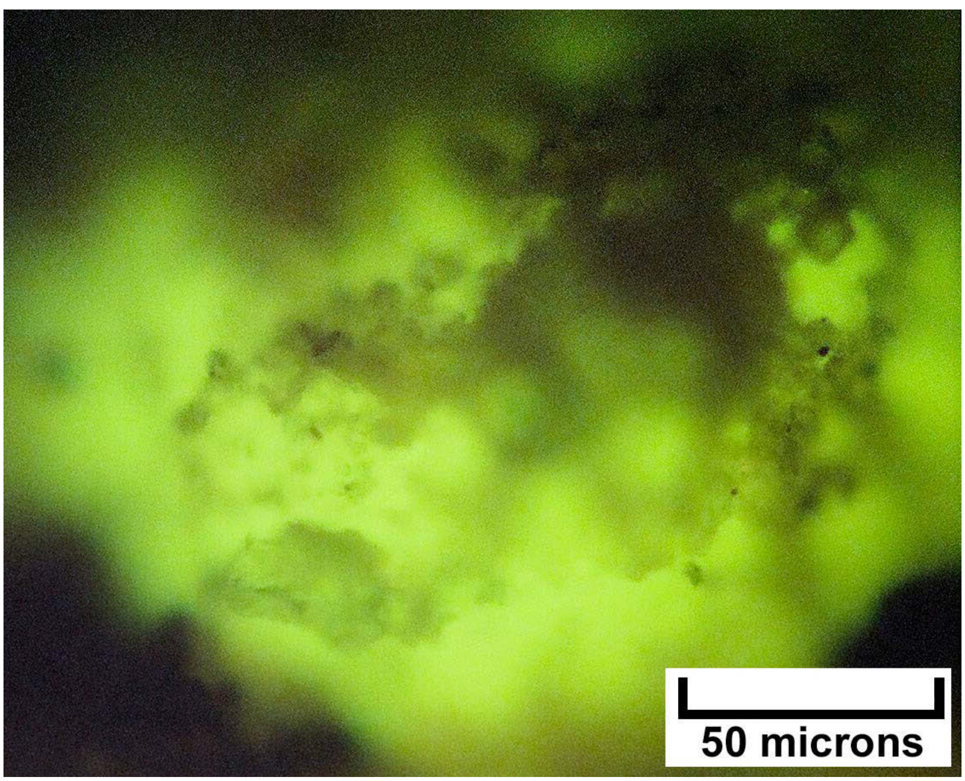
Digital microscope image (dry) – Cane Creek State #1-36 (Map #16), 7060-70 feet, C interval, dolomitic wackestone to packstone in which black bitumen appears to be present within the intercrystalline pores between dolomite crystals.



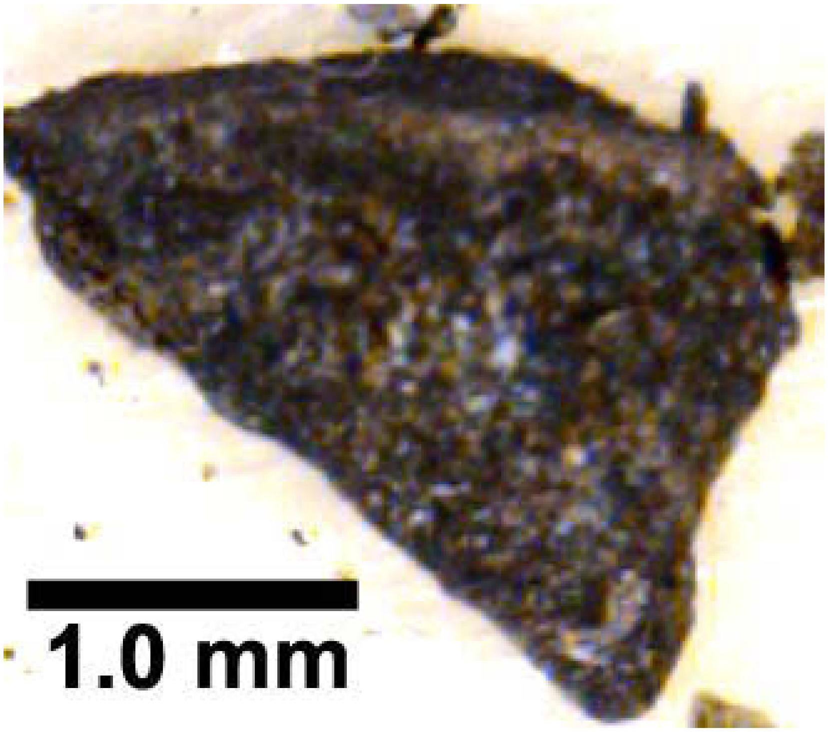
EF photomicrograph – Cane Creek State #1-36 (Map #16), 7060-70 feet, C interval, 2.3 visual epifluorescence rating in fine to medium dolomite with intercrystalline porosity, wackestone/packstone.



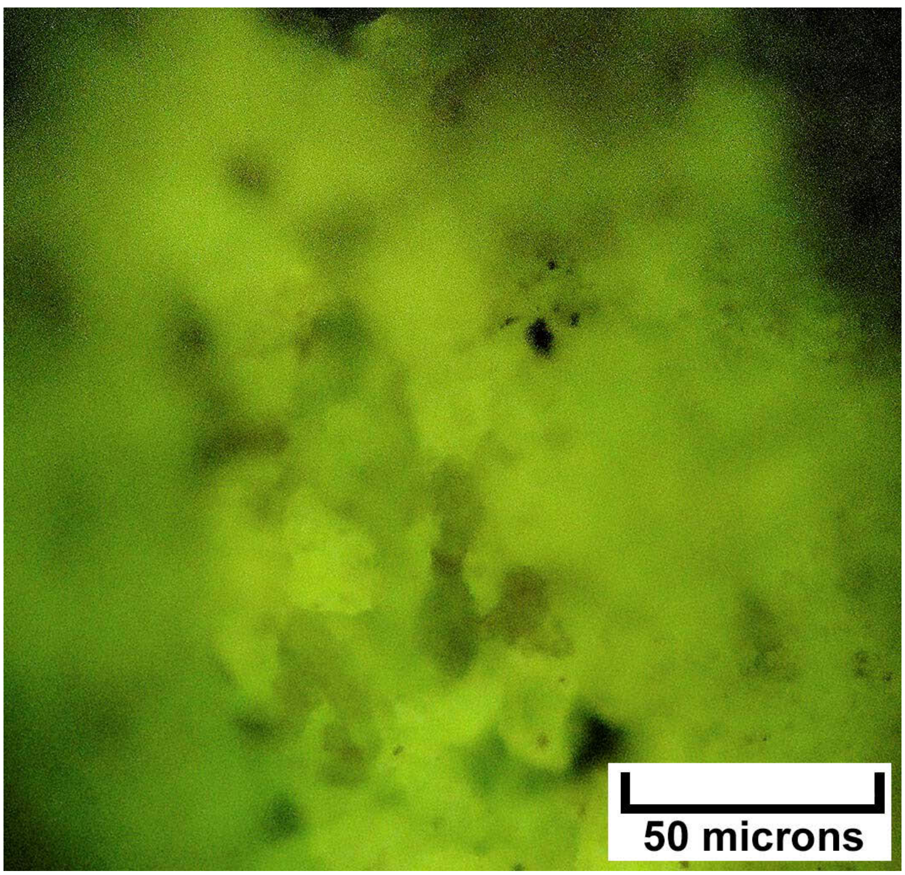
Digital microscope image (dry) – Cane Creek State #1-36 (Map #16), 7070-80 feet, C interval, pair of dark-colored dolomite cuttings from a porous microbialite interval. Note the abundant black bitumen that is present within the pore spaces of the microbial framework.



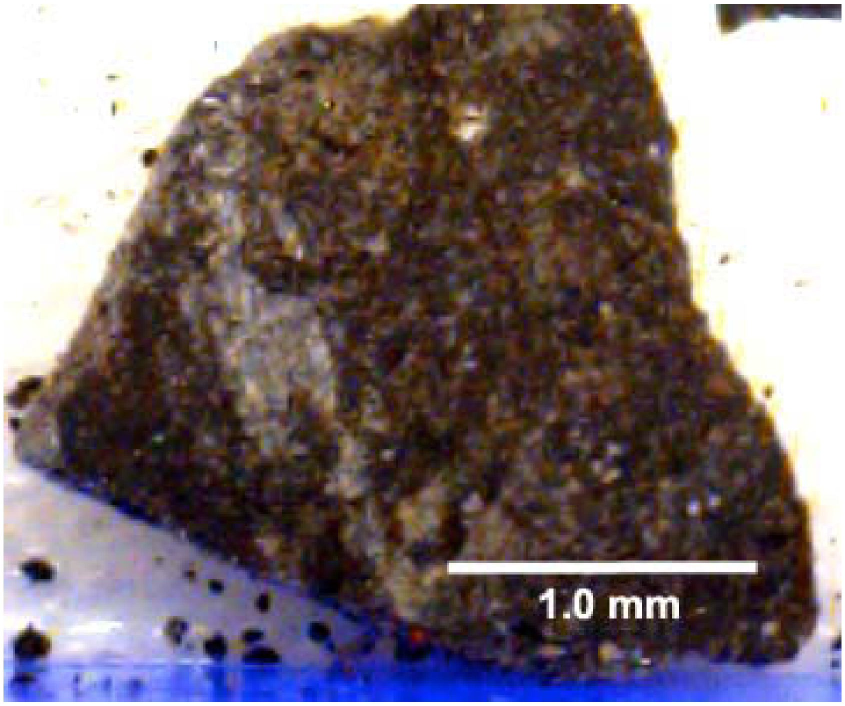
EF photomicrograph – Cane Creek State #1-36, (Map #16), 7070-80 feet, C interval, 2.1 visual epifluorescence rating in porous microcrystalline dolomite with excellent fluorescence in a possible microbial fabric.



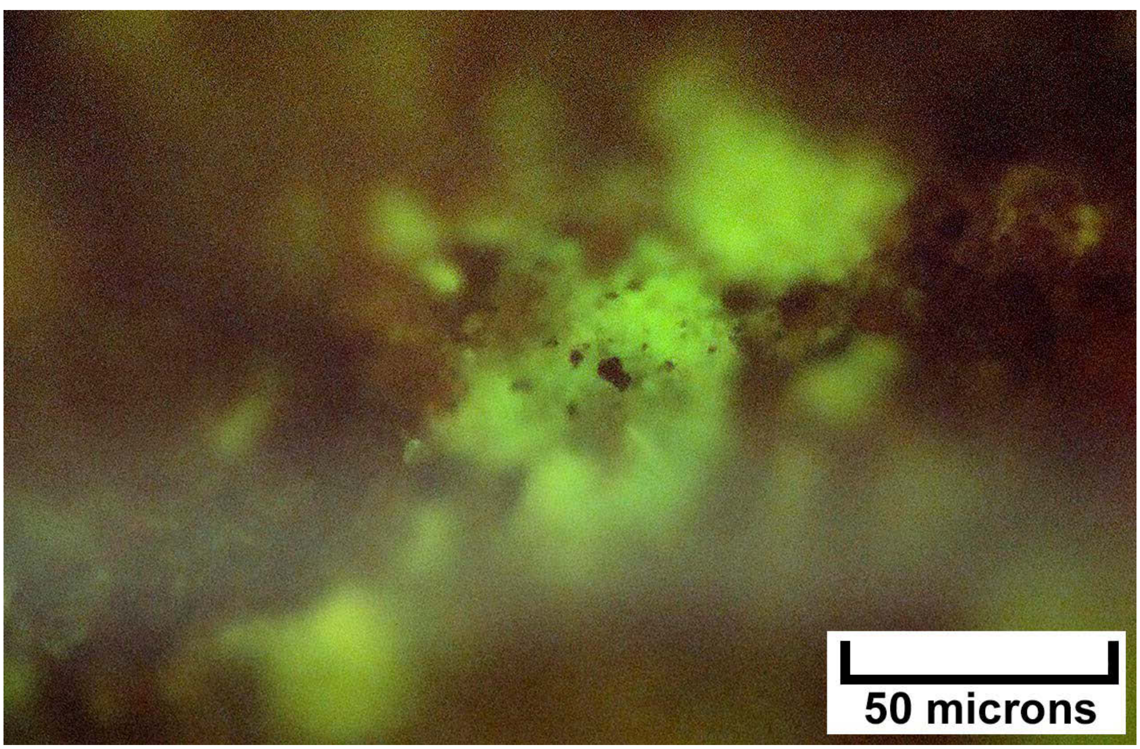
Digital microscope image (dry) – Cane Creek State #1-36 (Map 16), 7080-90 feet, C interval, dark-colored dolomite sample with hint of brown oil staining. Some of the black color is due to the presence of bitumen within the intercrystalline pore spaces.



EF photomicrograph – Cane Creek State #1-36 (Map #16), 7080-90 feet, C interval, 2.6 visual epifluorescence rating in slightly silty dolomite with fine to medium crystals, good intercrystalline and moldic pore space, bright fluorescence.

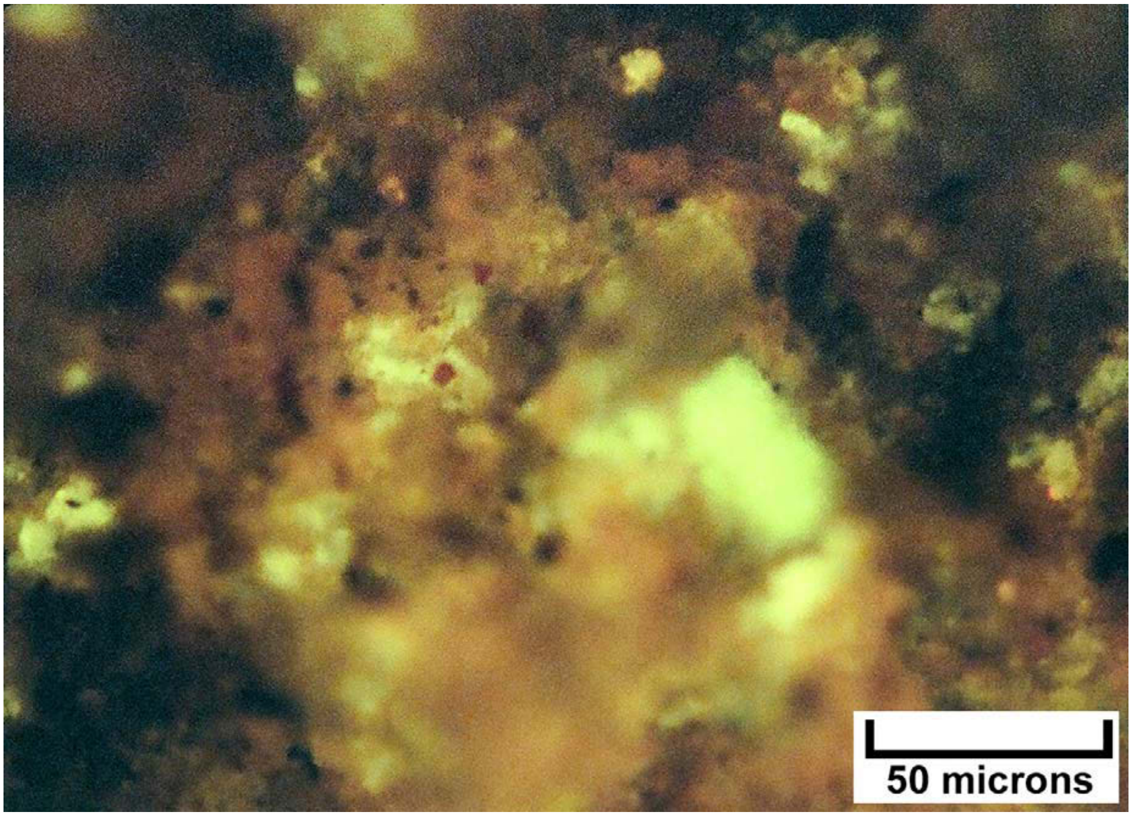


Digital microscope image (dry) – Red Rock Unit #1 (Map #17), 6850-60 feet, C interval, dolomite with medium to dark brown oil staining. A fine crystalline dolomite matrix does not contain silt grains. There appears to be some bitumen with the fine intercrystalline porosity along with the oil staining. An elongate white patch of probable anhydrite is present in the left center of this view.

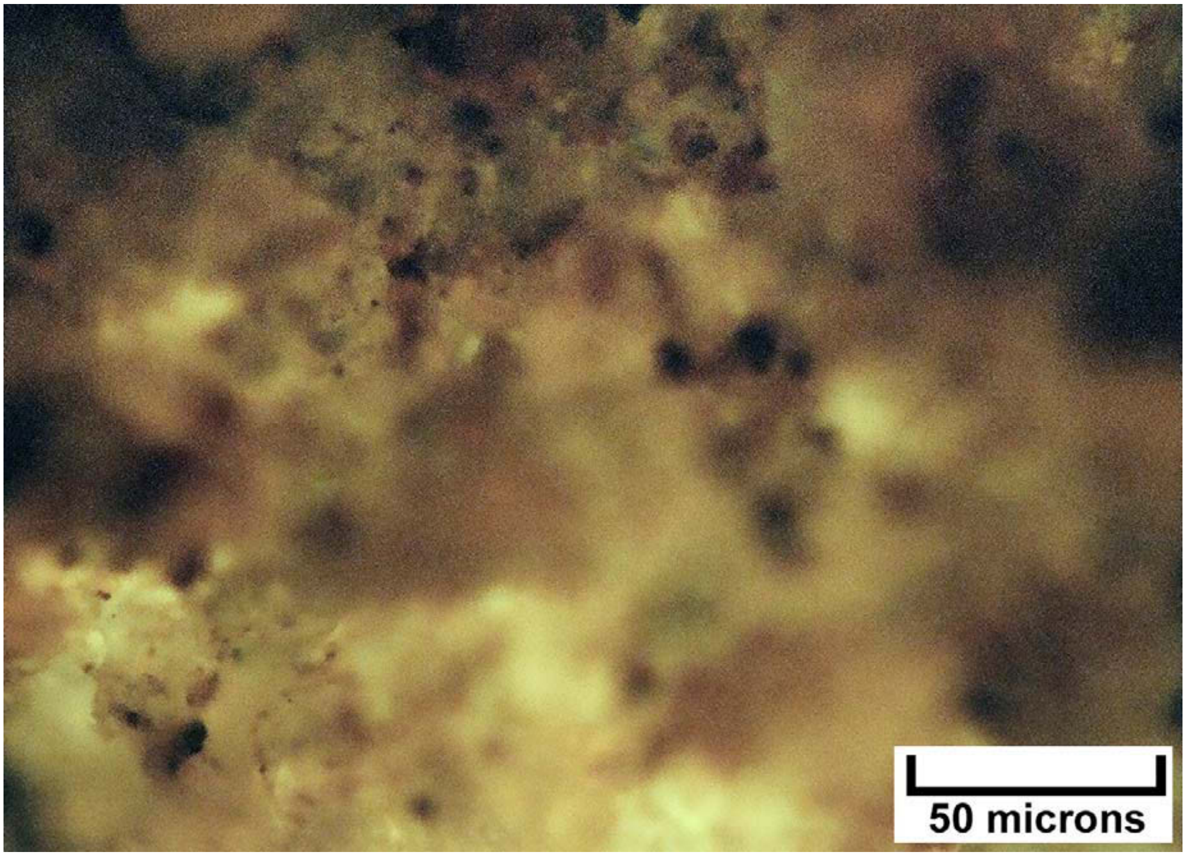


EF photomicrograph – Red Rock Unit #1 (Map #17), 6850-60 feet, C interval, 2.2 visual epifluorescence rating in medium crystalline dolomite with some interparticle porosity, possible packstone/grainstone.

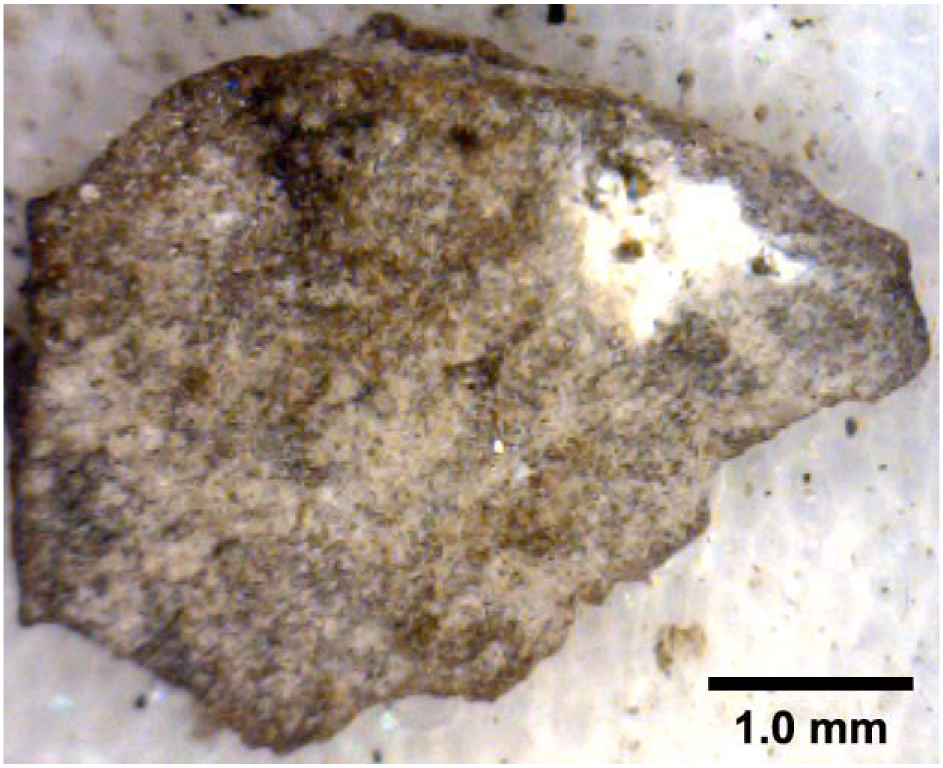
Digital microscope image (dry) – Red Rock Unit #1 (Map #17), 6860-70 feet, C interval, two samples of silty dolomite are shown here. The upper sample is a light gray silty sample with probable anydritic cement as well as a patch of black bitumen. The lower sample appears to contain abundant black bitumen patches in the silty dolomite matrix.



EF photomicrograph – Red Rock Unit #1 (Map #17), 6860-70 feet, C interval, 2.4 visual epifluorescence rating in dolomite with visible porosity associated with microbial fabric.



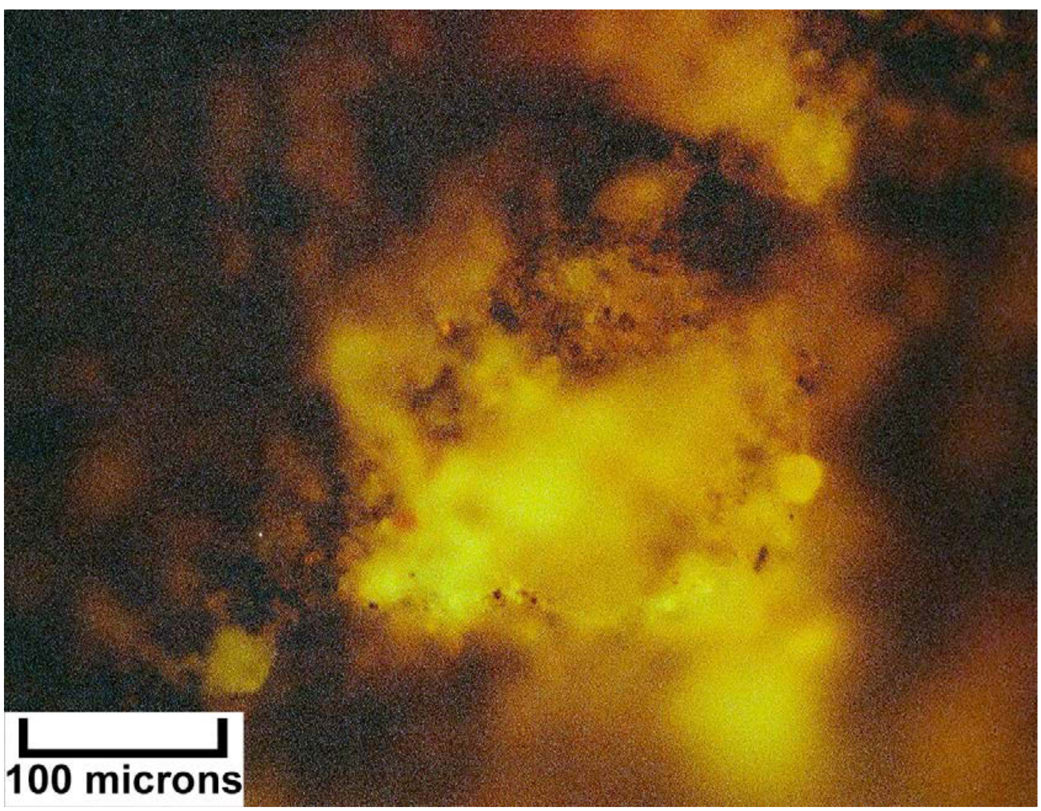
EF photomicrograph – Red Rock Unit #1 (Map #17), 6880-90 feet, C interval, 2.5 visual epifluorescence rating in dolomitic packstone/grainstone, fine to medium crystalline with possible visible porosity and opaque disseminated pyrite.



Digital microscope image (dry) – Lockhart Federal #1 (Map #18), 4765-70 feet, A interval, dolomite displaying light brown oil staining. Small, well-sorted grains (some skeletal and some coated grains) are visible within this porous dolomitized grainstone to packstone.

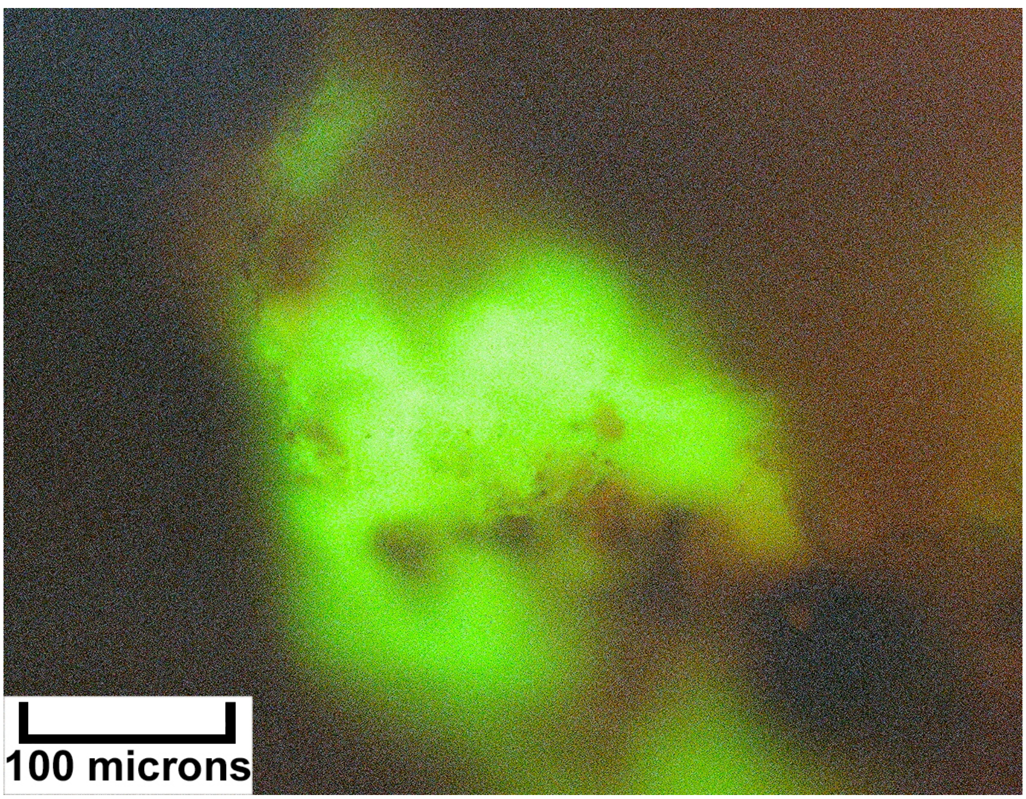
EF photomicrograph – Lockhart Federal #1 (Map #18), 4765-70 feet, A interval, 1.5 visual epifluorescence rating in dolomite crystal aggregate.

Digital microscope image (dry) – Lockhart Federal #1 (Map #18), 4780-85 feet, B interval, dolomite displaying patchy light brown oil staining. Grain outlines can be easily seen in this skeletal grainstone.

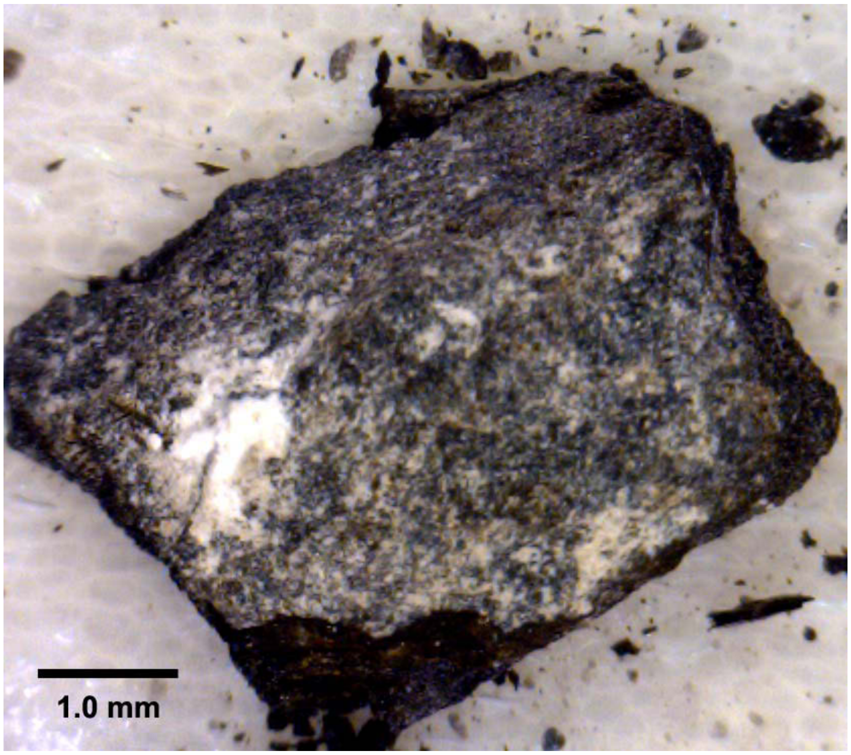


EF photomicrograph – Lockhart Federal #1 (Map #18), 4780-85 feet, B interval, 2.2 visual epifluorescence rating in crystalline dolomite with patchy good epifluorescence.

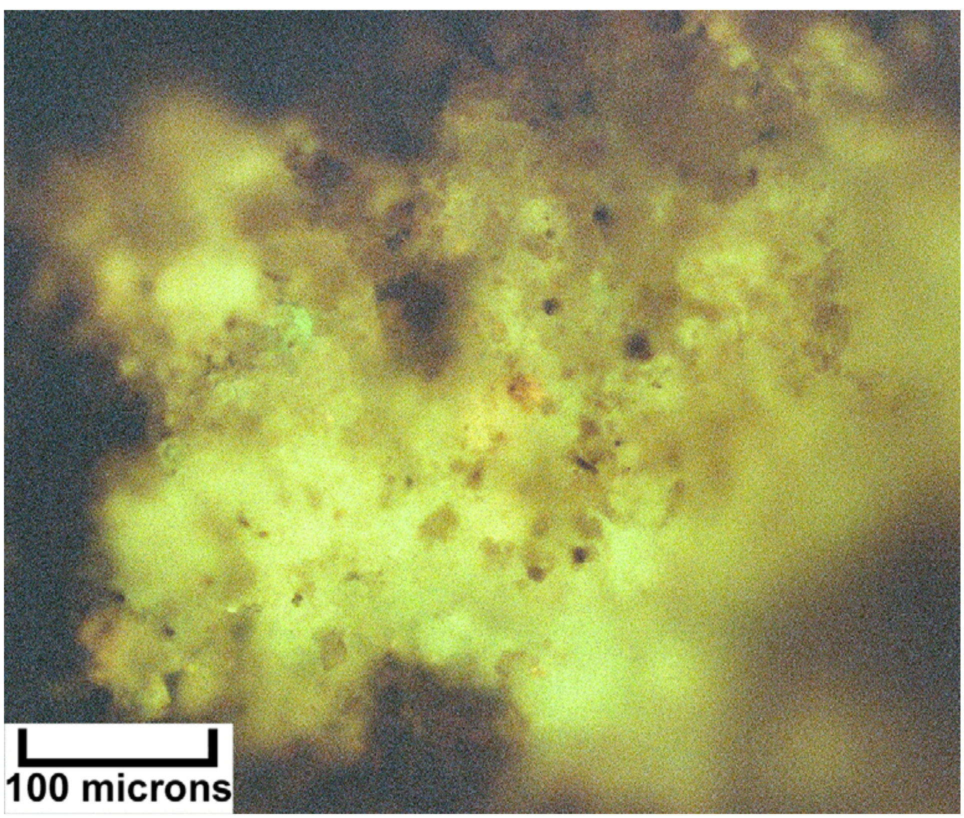
Digital microscope image (dry) – Lockhart Federal #1 (Map 18), 4785-90 feet, B interval, dolomite with patchy black bitumen concentrations as well as light brown oil staining within the matrix porosity. Possible organic (microbial?) structures or clots surrounded by carbonate grains can be seen in this sample.



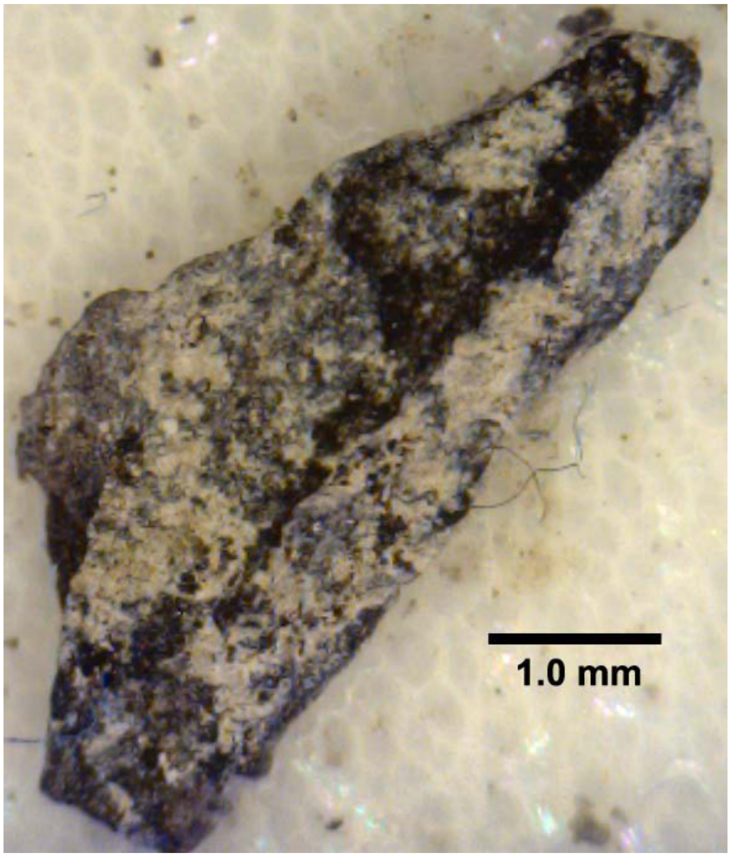
EF photomicrograph – Lockhart Federal #1 (Map #18), 4785-90 feet, B interval, 2.5 visual epifluorescence rating in anhydrite lathes and organic structures.



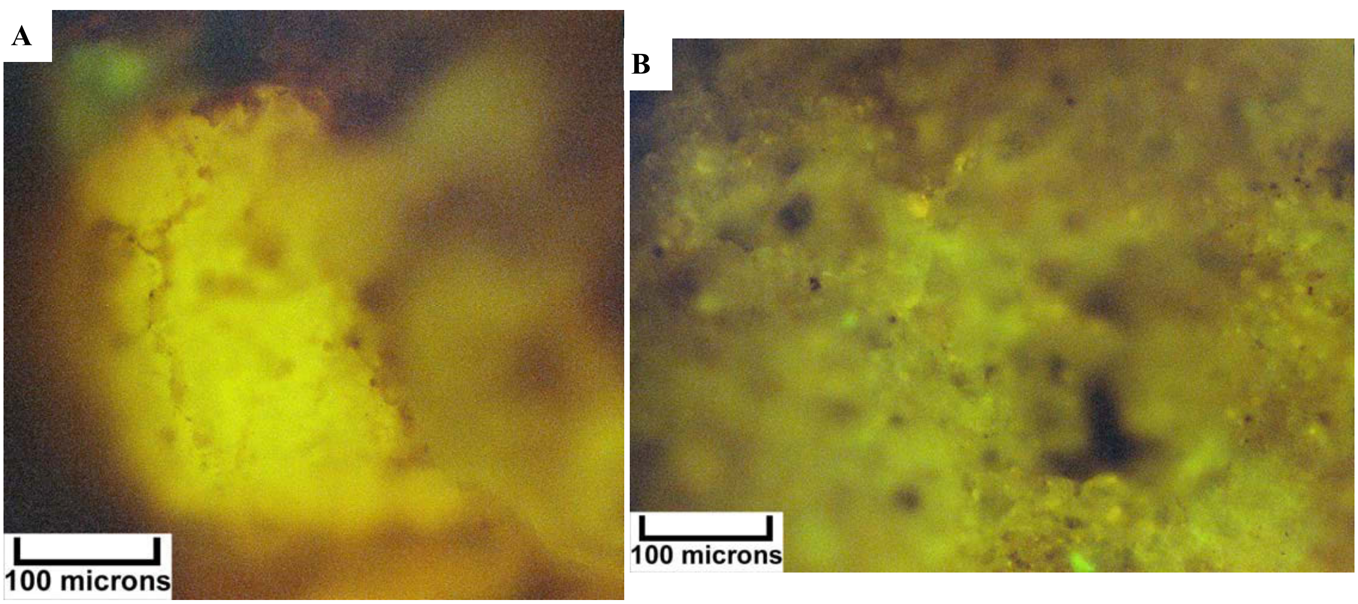
Digital microscope image (dry) – Lockhart Federal #1 (Map #18), 4800-10 feet, C interval, dolomite to silty dolomite with layered and possibly laminated microstructures. Note the black (bitumen-bearing) matrix with patchy dark brown oil staining. The white materials may be artifacts of anhydrite within the rock section.



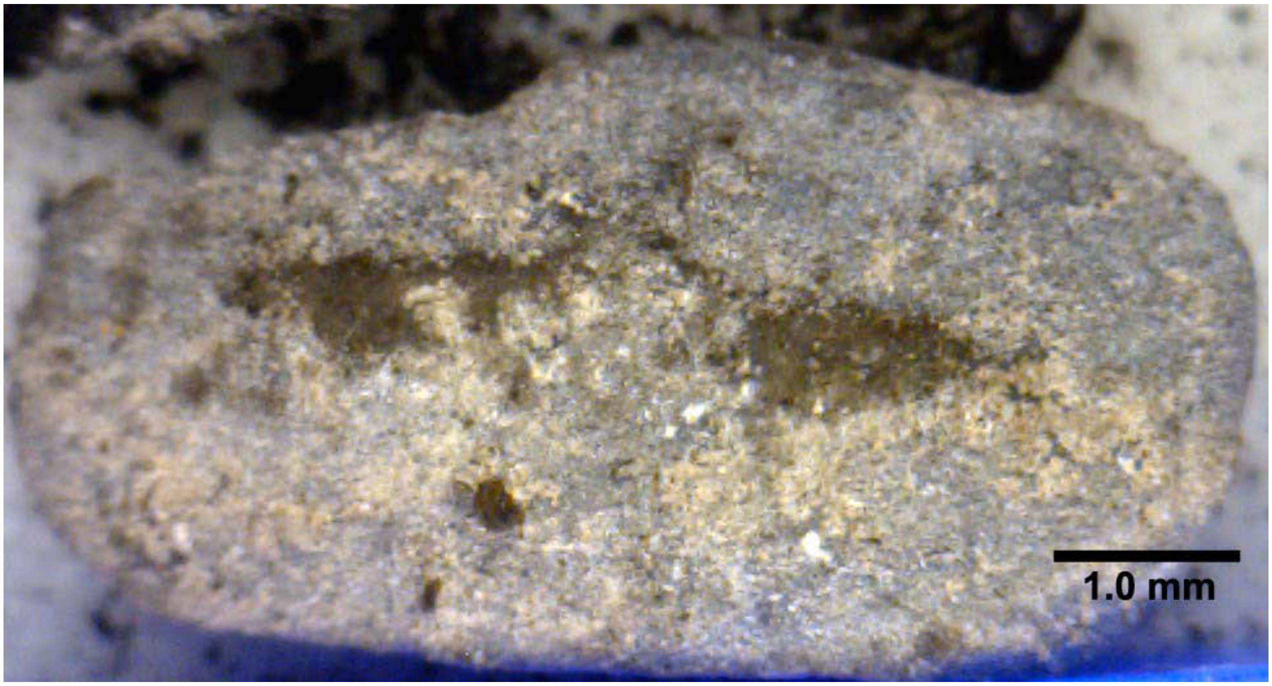
EF photomicrograph – Lockhart Federal #1 (Map #18), 4800-10 feet, C interval, 2.4 visual epifluorescence rating in fluorescing oil saturated dolomite.



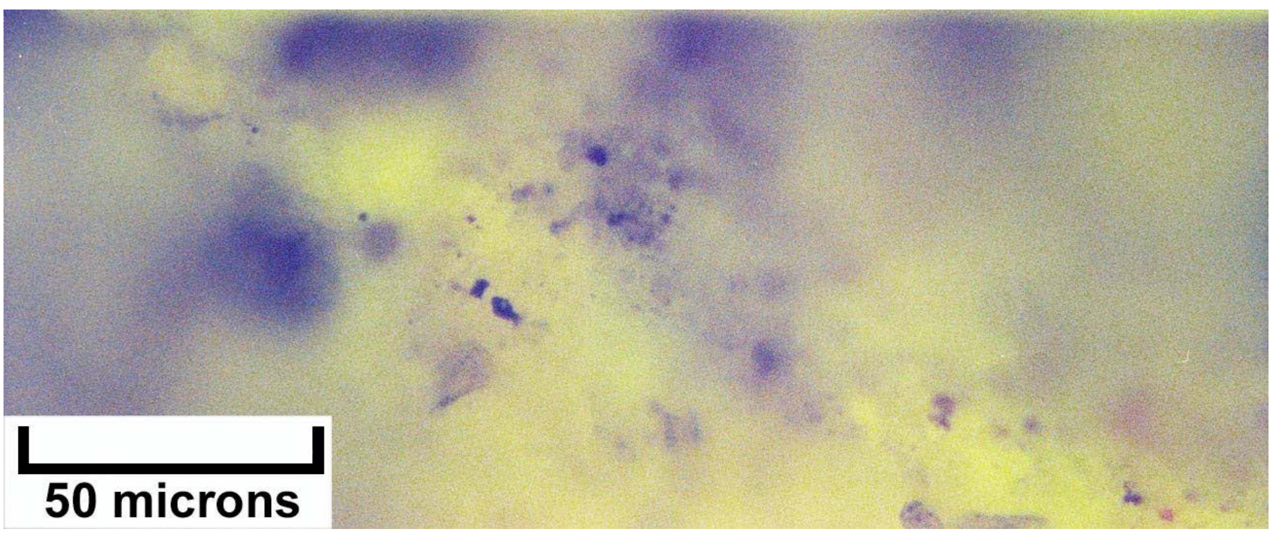
Digital microscope image (dry) – Lockhart Federal #1 (Map #18), 4815-20 feet, C interval, elongate sample composed of a dolomite to limy dolomite matrix. The linear nature of this cutting sample as well as the alignment of the black material (possibly bitumen) is probably indicative of a naturally fractured rock interval.



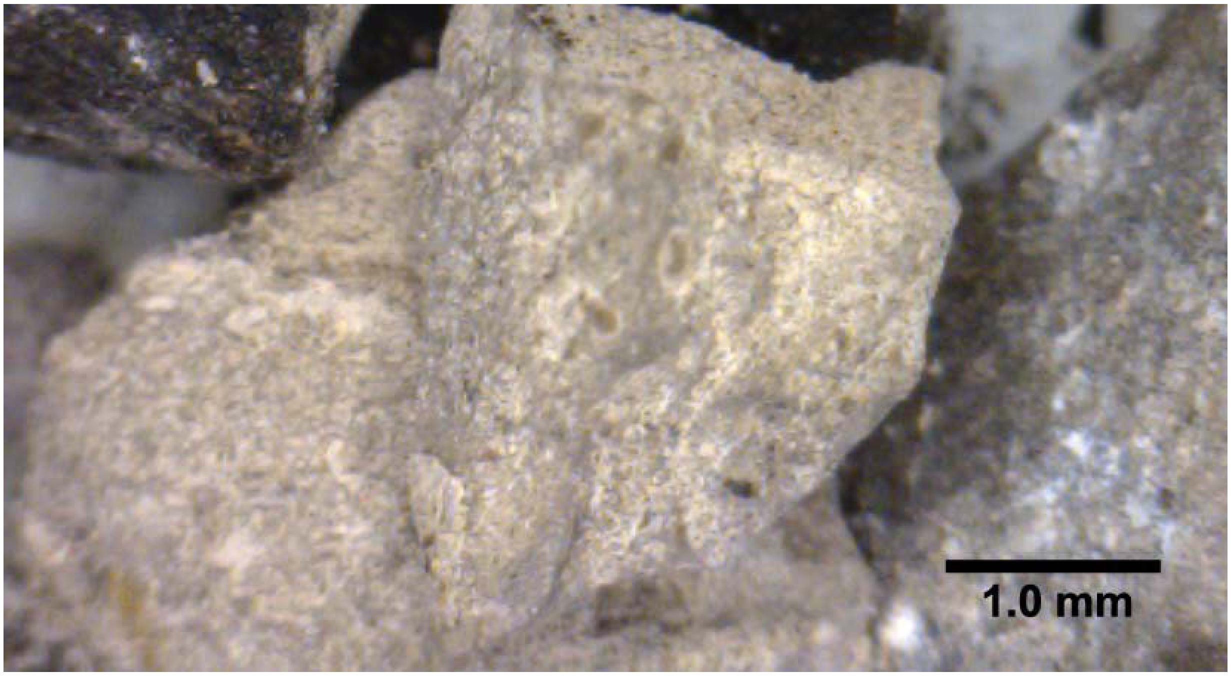
EF photomicrographs – Lockhart Federal #1 (Map #18), 4815-20 feet, C interval. A: 3.0 visual epifluorescence rating in fractured dolomite with live oil films. B: 3.0 visual epifluorescence rating in fractured dolomite with live oil films (same sample, different area on sample).



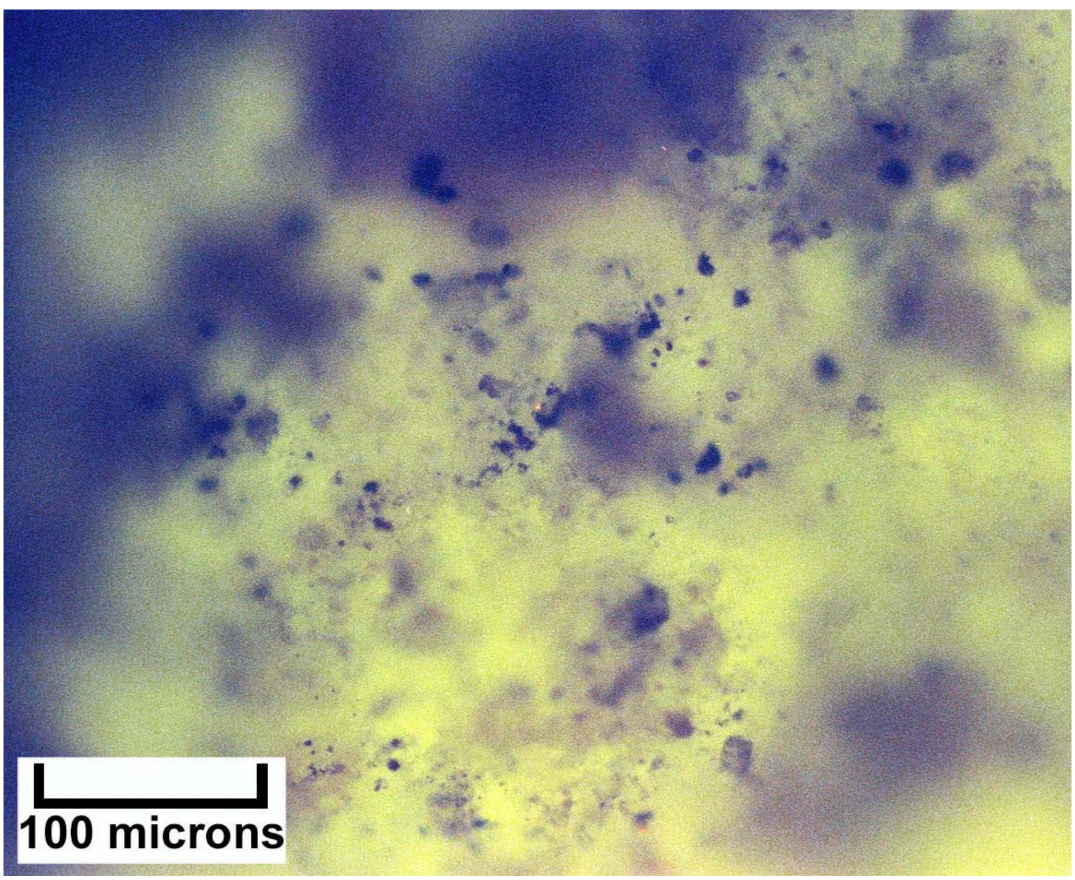
Digital microscope image (dry) – Government #B-1 (Map #20), 7565-75 feet, A interval, limy and silty dolomite with very small patches of possible light brown oil staining. Note the intersecting pair of linear fracture traces.



EF photomicrograph – Government #B-1 (Map #20), 7565-75 feet, A interval, 3.2 visual epifluorescence rating in microcrystalline dolomite, floating silt grains, very bright oil fluorescence.

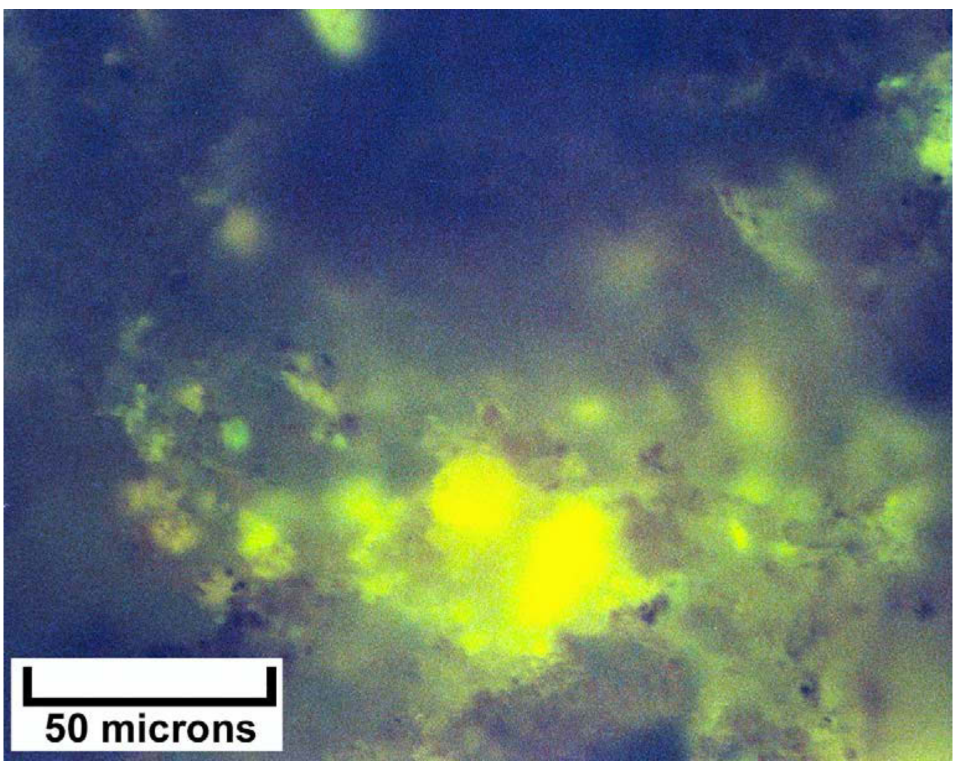


Digital microscope image (dry) – Government #B-1 (Map #20), 7575-85 feet, A interval, portions of two cuttings samples of light-colored silty dolomite. Possible carbonate grains can also be seen among the silty matrix. Note the very light brown oil staining.

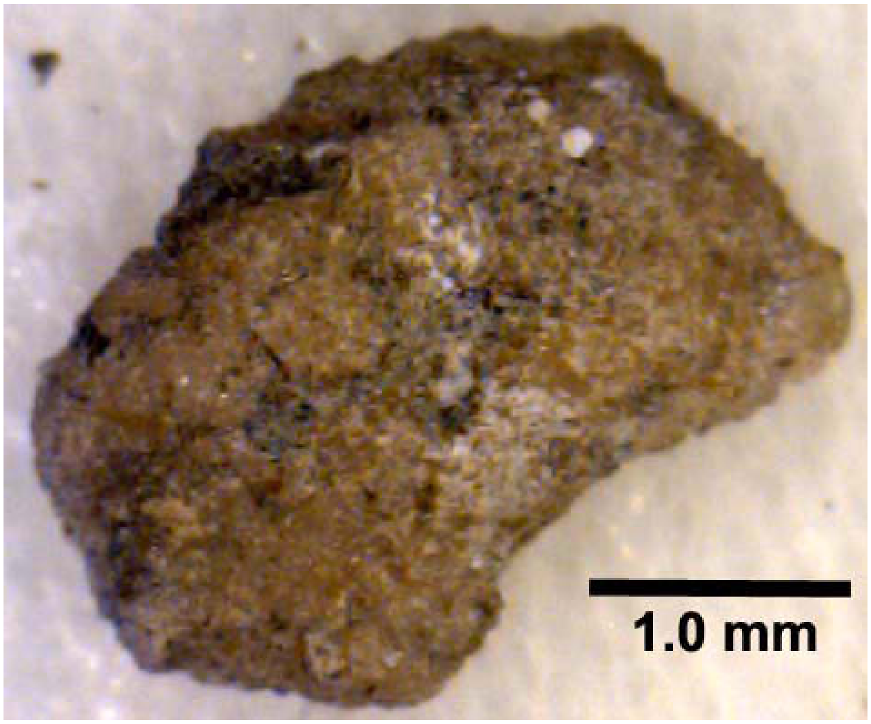


EF photomicrograph – Government #B-1 (Map #20), 7575-85 feet, A interval, 3.1 visual epifluorescence rating in finely crystalline dolomite, grainstone/packstone with occasional silt grains and disseminated pyrite, low visible porosity.

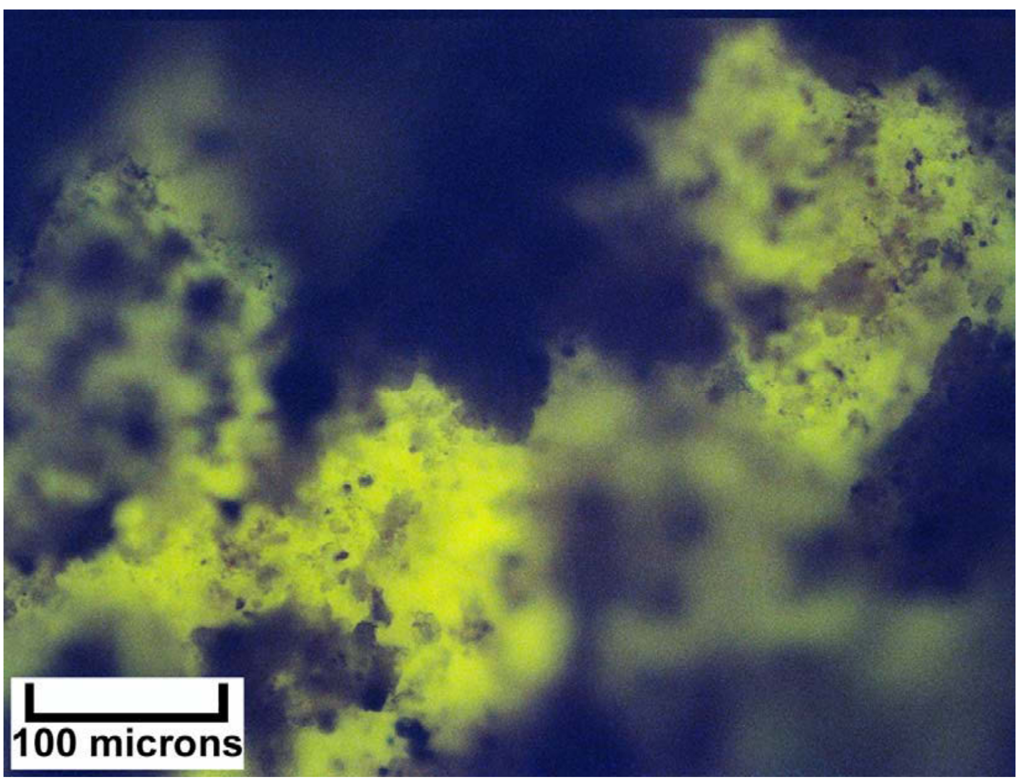
Digital microscope image (dry) – Government #B-1 (Map #20), 7610-20 feet, B interval, silty dolomite displaying a packstone texture as well as patchy light brown oil staining. Note the white concentration of probable salt (halite) and anhydrite. In addition, there are some small replacement pyrite crystals.



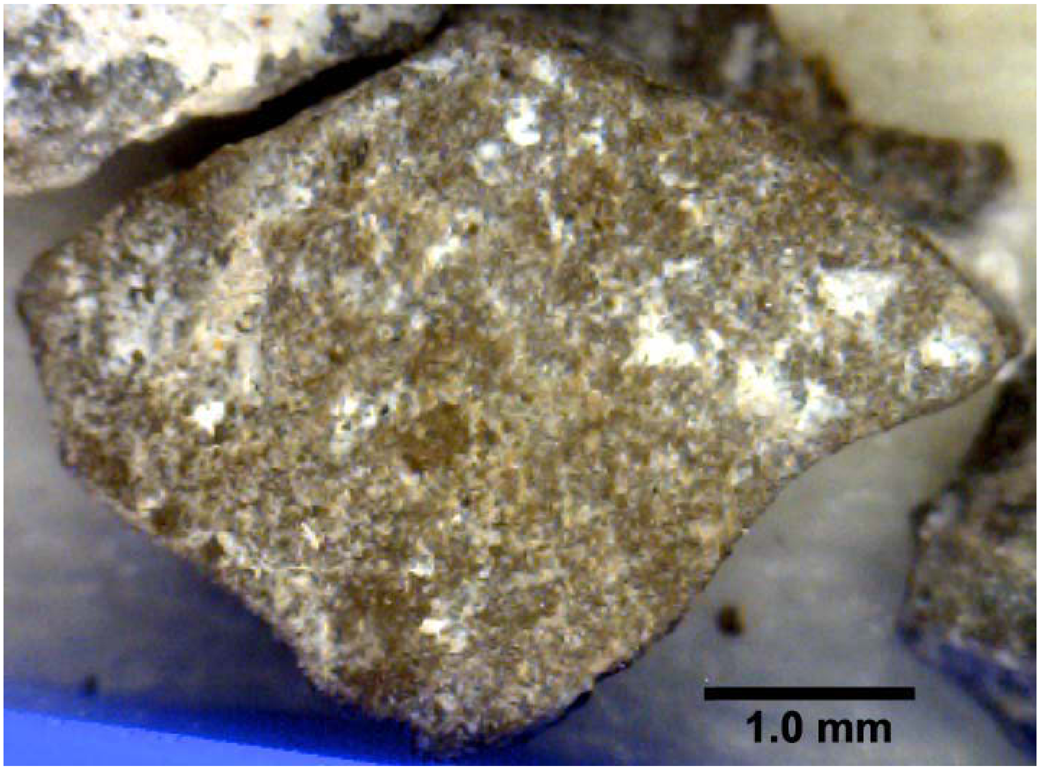
EF photomicrograph – Government #B-1 (Map #20), 7610-20 feet, B interval, 2.3 visual epifluorescence rating in medium crystalline dolomite, silty wackestone/ packstone with some possible salt plugging.



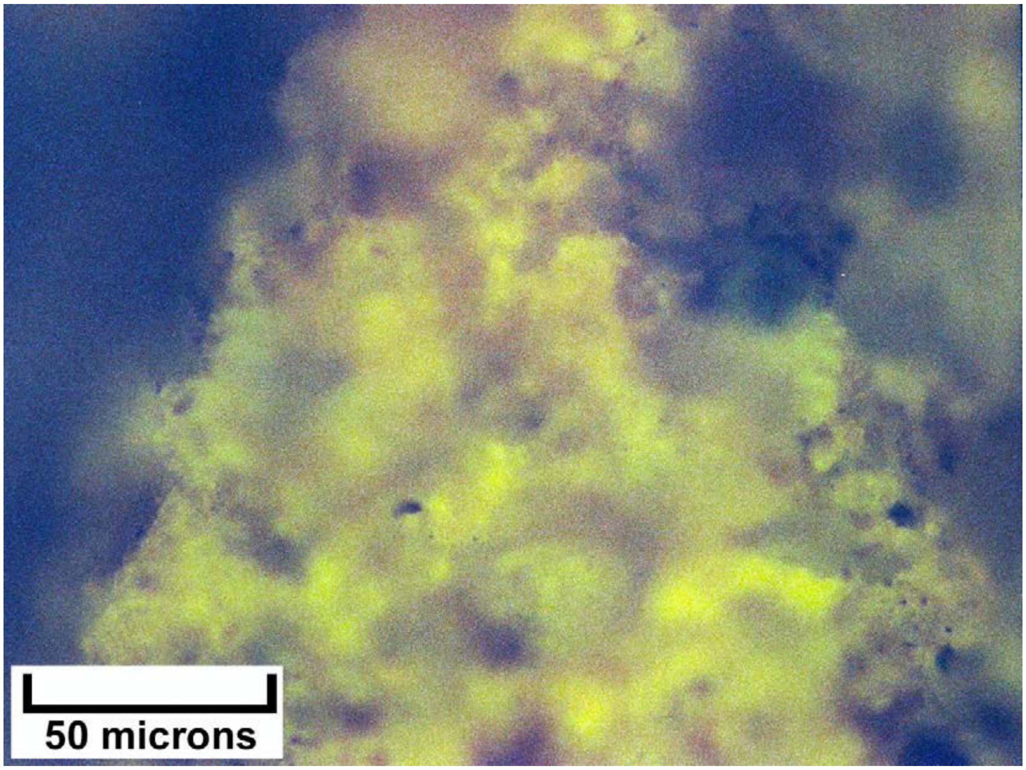
Digital microscope image (dry) – Government #B-1 (Map #20), 7640-50 feet, B interval, silty dolomite with medium brown oil staining. This packstone to wackestone contains "floating" carbonate grains in a muddy matrix as well as some pyrite.



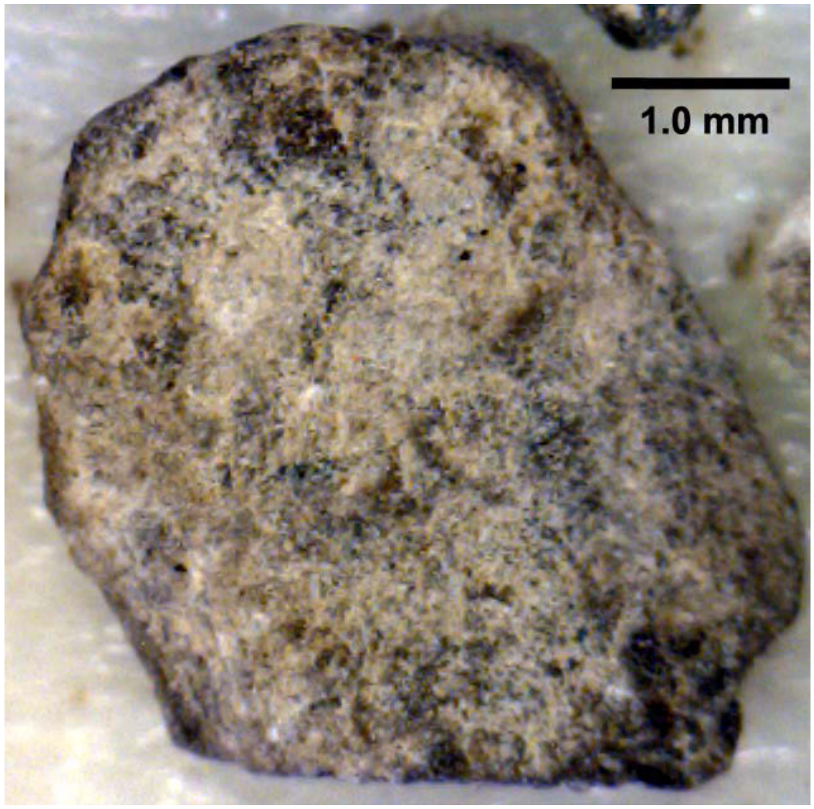
EF photomicrograph – Government #B-1 (Map #20), 7640-50 feet, B interval, 2.9 visual epifluorescence rating in silty microcrystalline dolomite, wackestone/packstone with bright fluorescence, possible anhydrite.



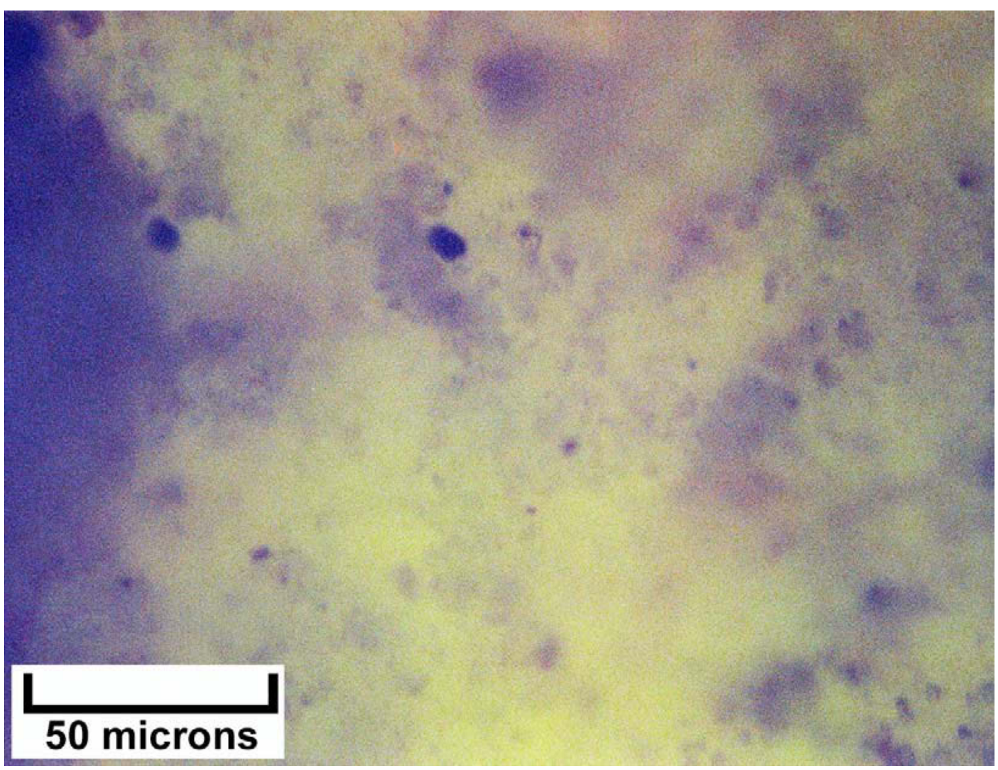
Digital microscope image (dry) – Government #B-1 (Map #20), 7670-80 feet, C interval, dolomite with patches of medium brown oil staining. This grainstone to packstone contains both small skeletal and non-skeletal grains.



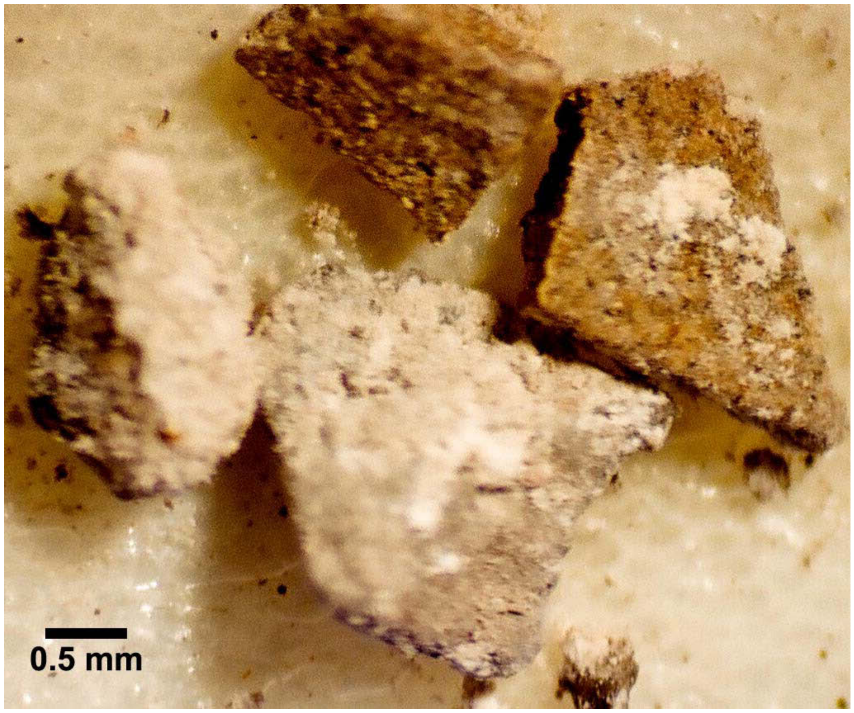
EF photomicrograph – Government #B-1 (Map #20), 7670-80 feet, C interval, 2.7 visual epifluorescence rating in silty medium crystalline dolomite with modest visible porosity, grainstone/packstone with bright fluorescence.



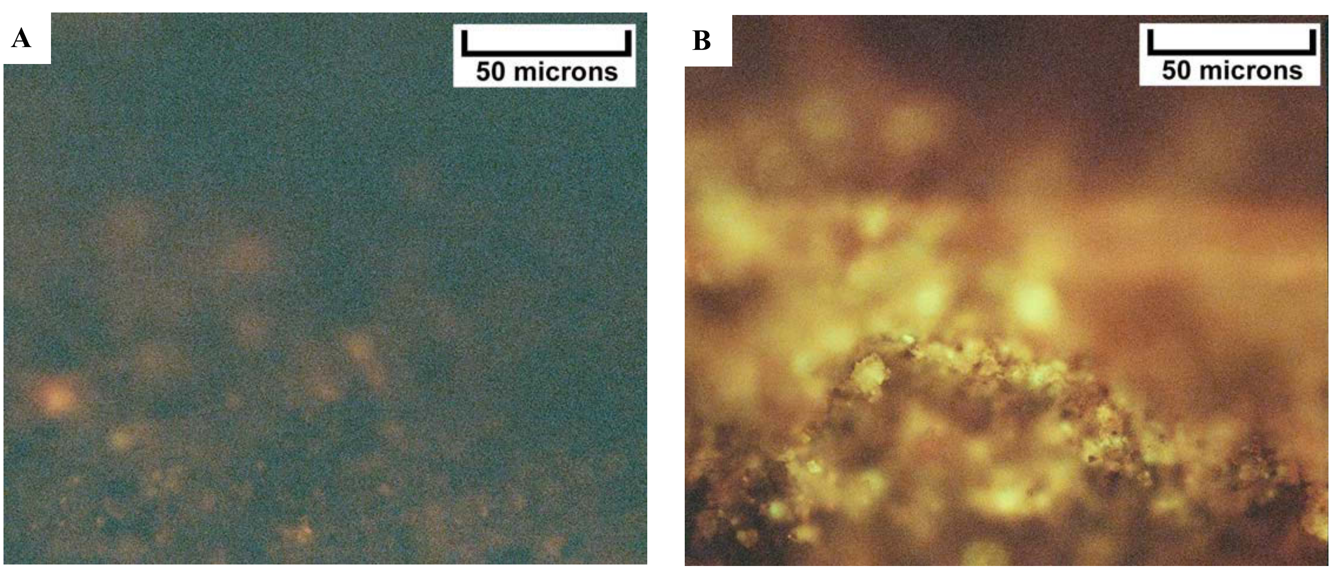
Digital microscope image (dry) – Government #B-1 (Map #20), 7710-20 feet, C interval, dolomite with porosity partially filled with black bitumen.



EF photomicrograph – Government #B-1 (Map #20), 7710-20 feet, C interval, 2.9 visual epifluorescence rating in fine to medium crystalline dolomite, packstone/grainstone, low visible porosity, probable microporosity, with very bright fluorescence.

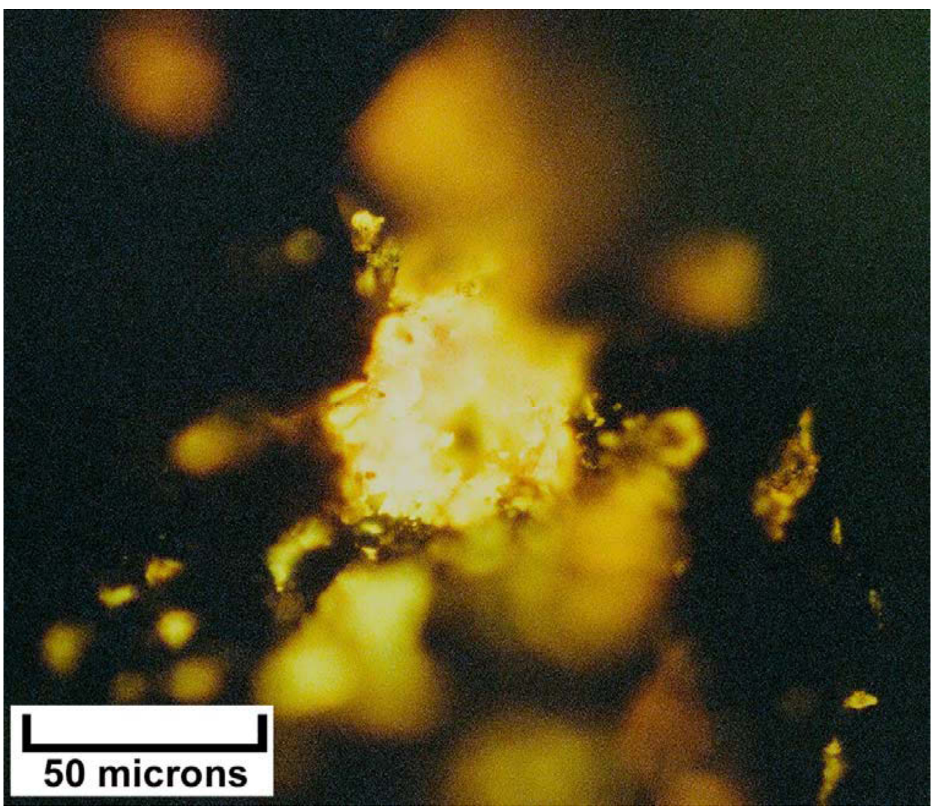


Binocular microscope image (wet) – Horsehead Unit #1 (Map #21), 6290-6300 feet, A interval, slightly dolomitic shale with abundant sulfides.

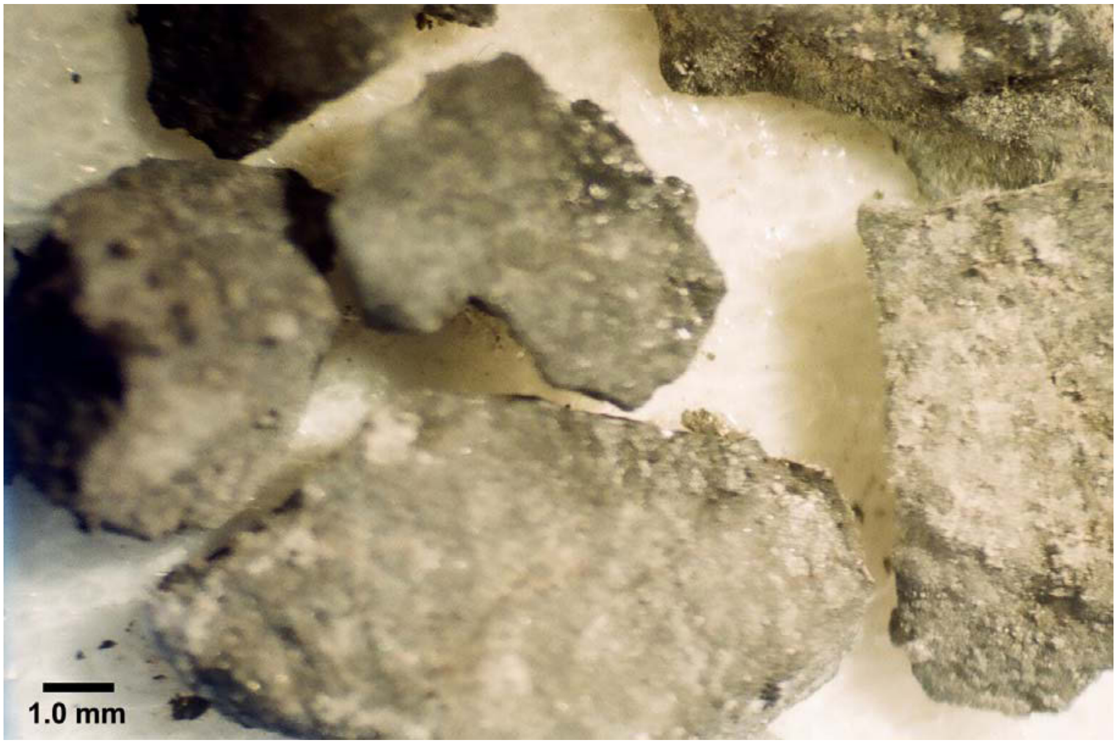


EF photomicrographs – Horsehead Unit #1 (Map #21), 6290-6300 feet, A interval, 0.7 visual epifluorescence rating (A) and 1.3 visual epifluorescence rating (B) in dolomitic shale to silty dolomitic shale.

Binocular microscope image (dry) – Horsehead Unit #1 (Map #21), 6300-10 feet, A interval, mostly dark brown to dark gray shale with minor amount of dark brown microcrystalline dolomite.

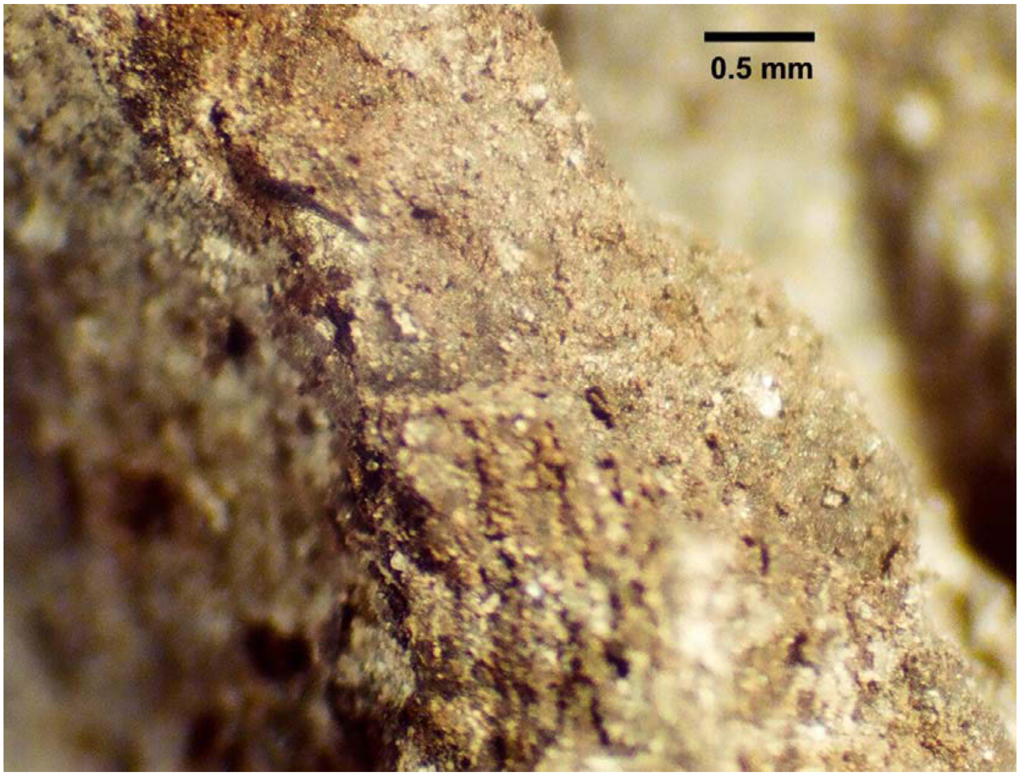


EF photomicrograph – Horsehead Unit #1 (Map #21), 6300-10 feet, A interval, 1.7 visual epifluorescence rating in dolomitic shale, slightly silty.



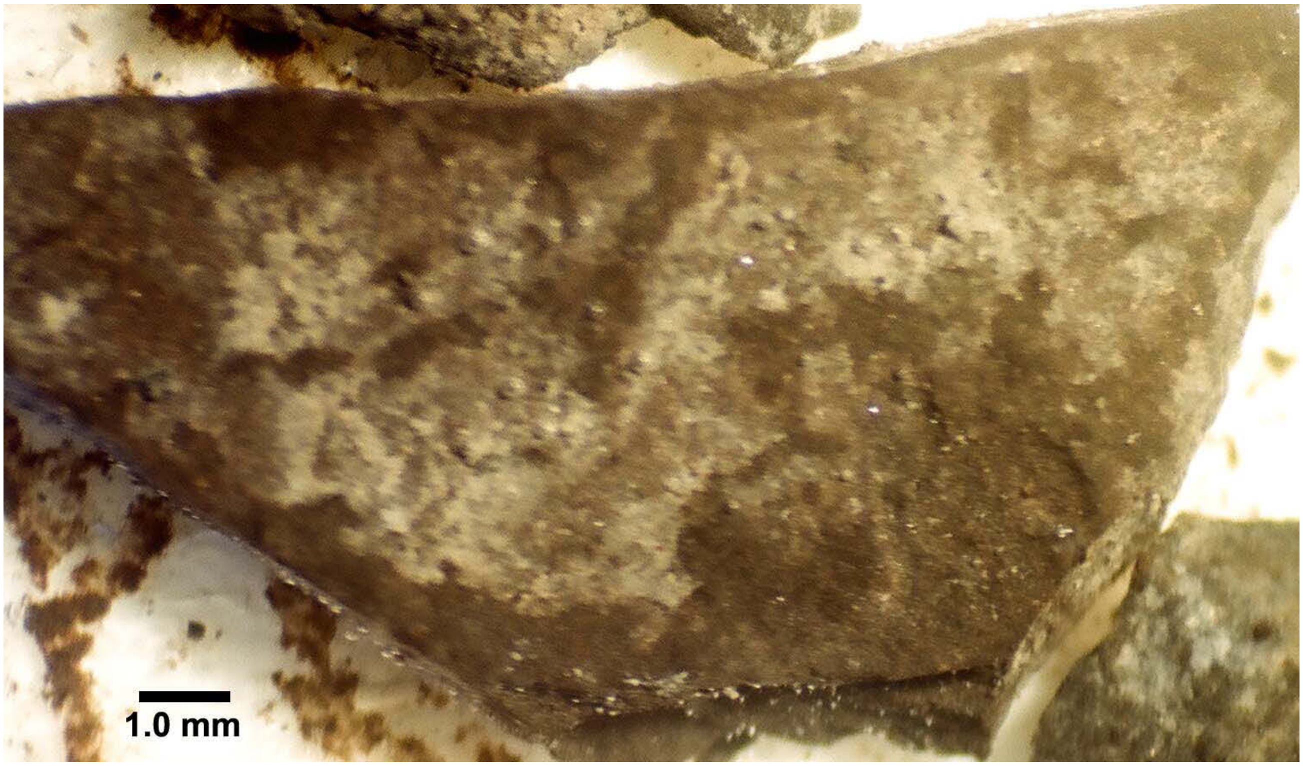
Binocular microscope image (dry) – Horsehead Unit #1 (Map #21), 6310-20 feet, B interval, mostly dark gray shale with minor amount of microcrystalline dolomite.

EF photomicrograph – Horsehead Unit #1 (Map #21), 6310-20 feet, B interval, 1.7 visual epifluorescence rating in dolomitic shale to silty shale.

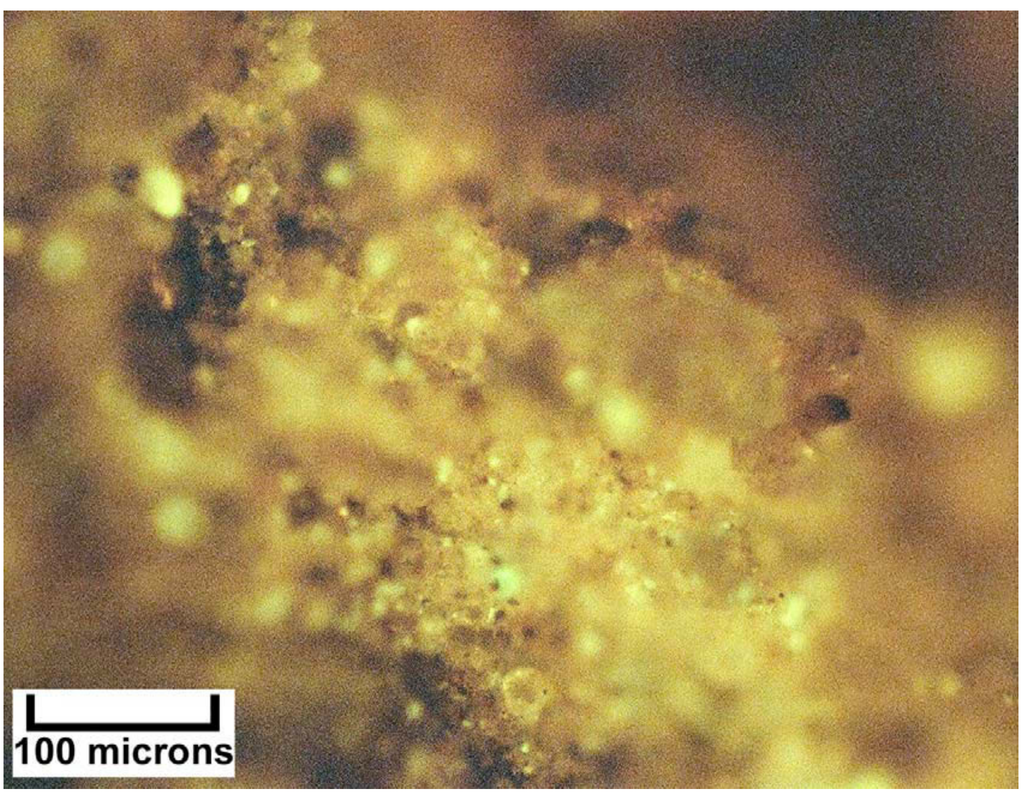


Binocular microscope image (dry) – Horsehead Unit #1 (Map #21), 6320-30 feet, B interval, microcrystalline dolomite with microporosity and light brown oil staining.

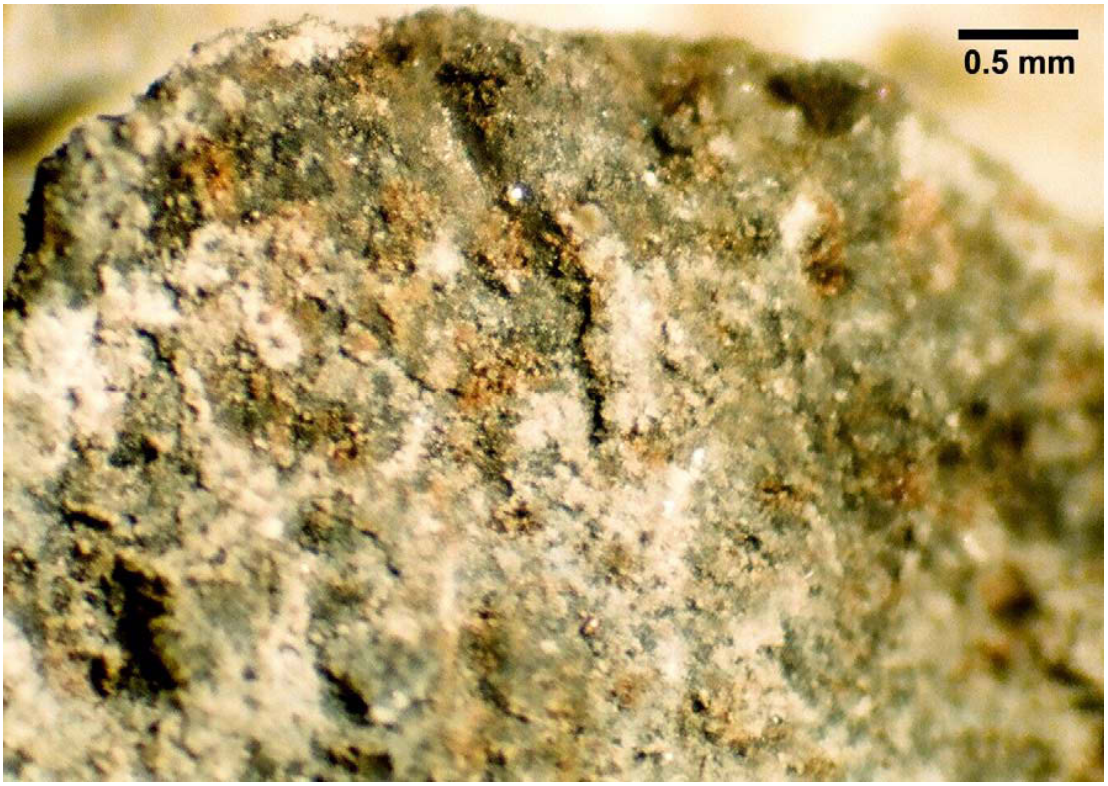
EF photomicrograph – Horsehead Unit #1 (Map #21), 6320-30 feet, B interval, 2.2 visual epifluorescence rating in microcrystalline dolomite with microporosity and probable oil saturation plus saline minerals (anhydrite or halite).



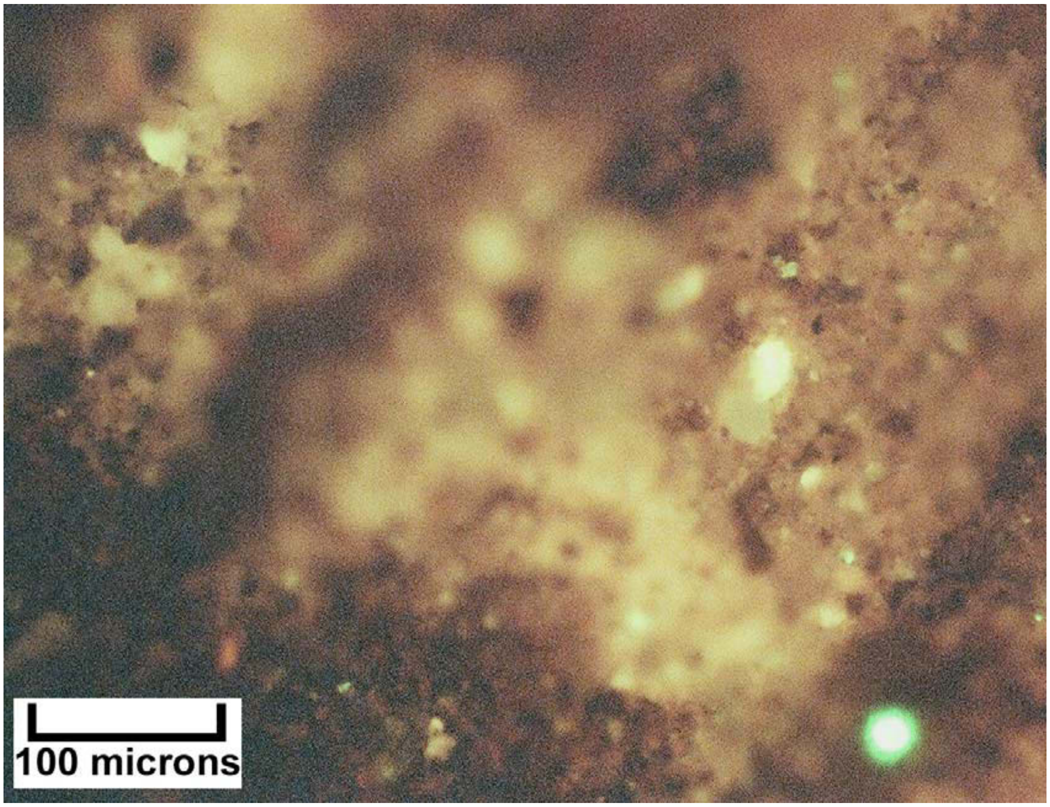
Binocular microscope image (wet) – Horsehead Unit #1 (Map #21), 6330-40 feet, B interval, 50% microcrystalline dolomite, bioturbated, either highly organic or oil saturated, 50% slightly dolomitic shale.



EF photomicrograph – Horsehead Unit #1 (Map #21), 6330-40 feet, B interval, 3.0 visual epifluorescence rating in dolomite and dolomitic shale.

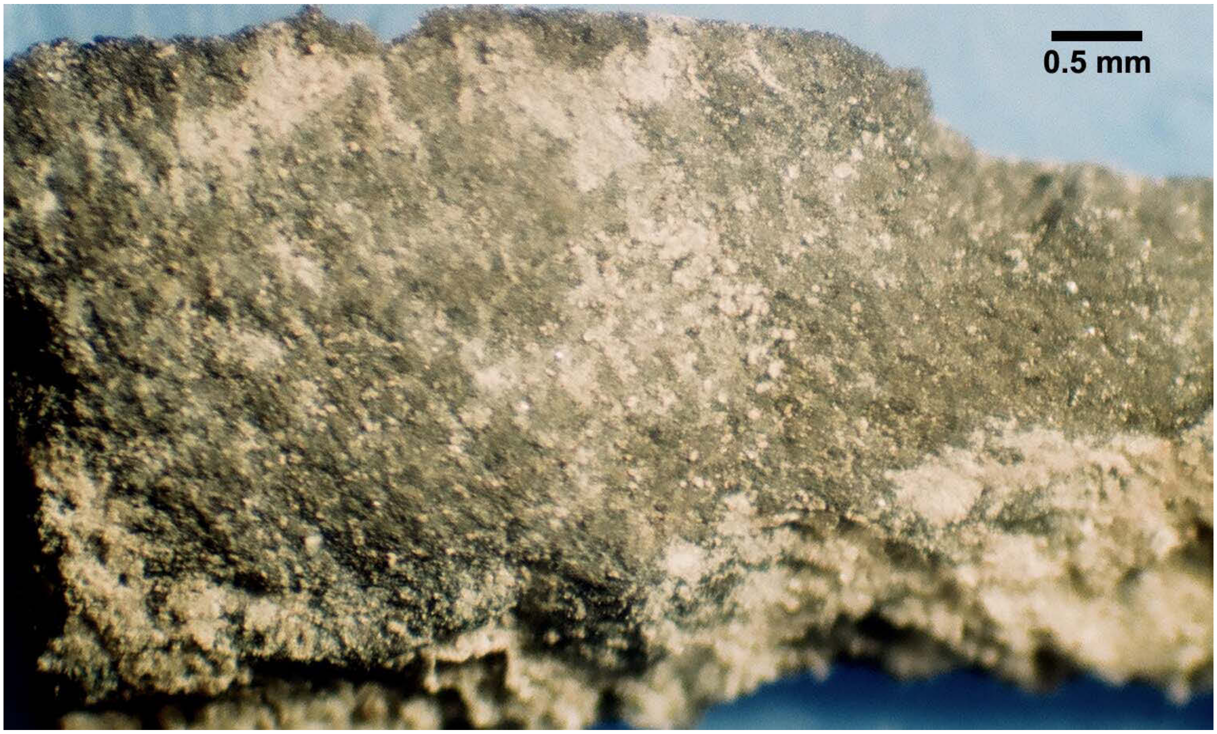


Binocular microscope image (dry) – Horsehead Unit #1 (Map #21), 6340-50 feet, B interval, mostly highly organic black to dark gray shale with isolated patches or small nodes of incipient dolomite forming as replacement of phosphatic pellets.

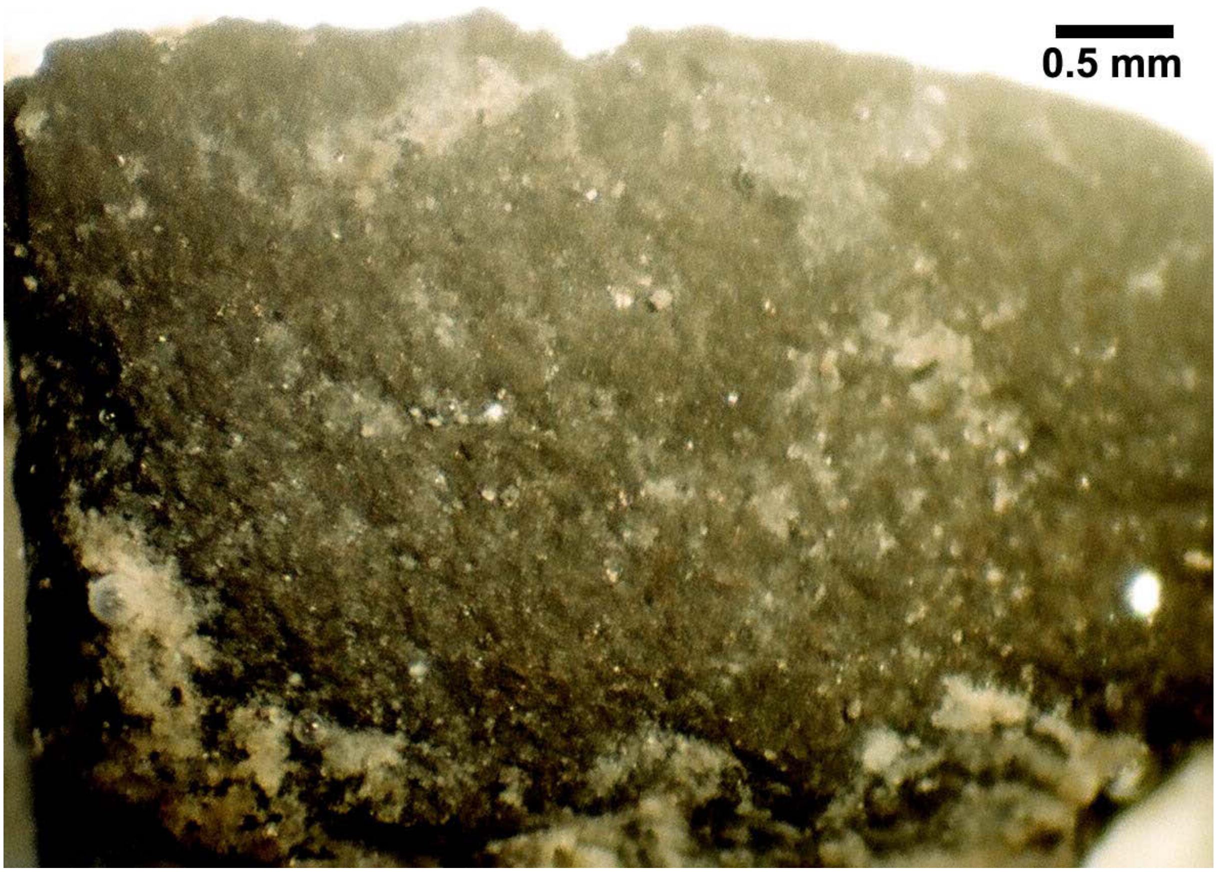


EF photomicrograph – Horsehead Unit #1 (Map #21), 6340-50 feet, B interval, 1.8 visual epifluorescence rating in shale and highly dolomitic shale.

A

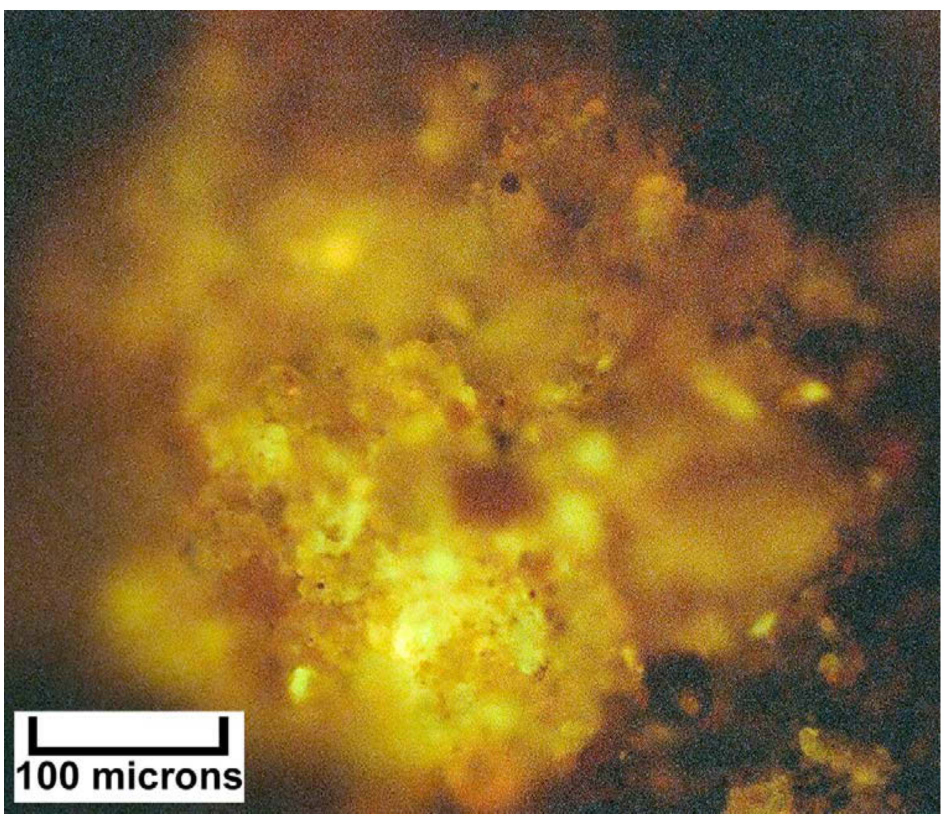


B

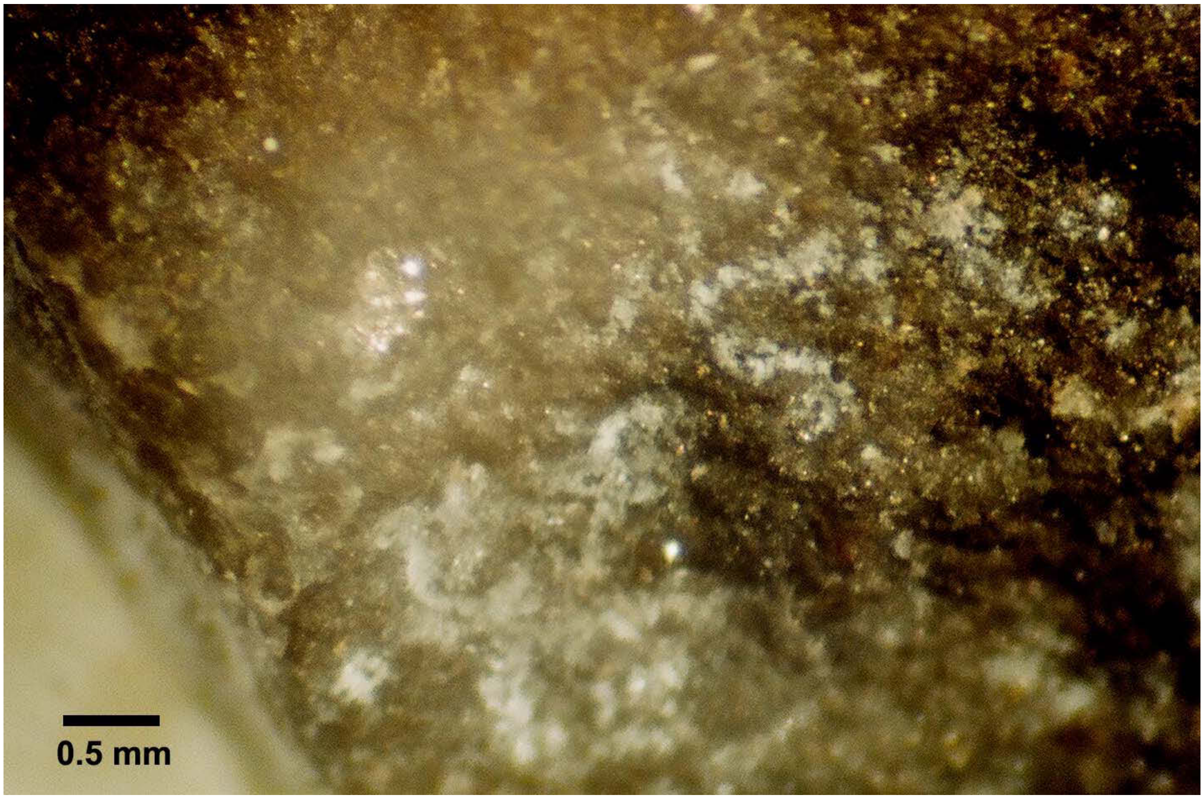


Binocular microscope images (A: dry, B: wet) – Horsehead Unit #1 (Map #21), 6350-60 feet, C interval, representative peloidal black organic shale, non-laminated.

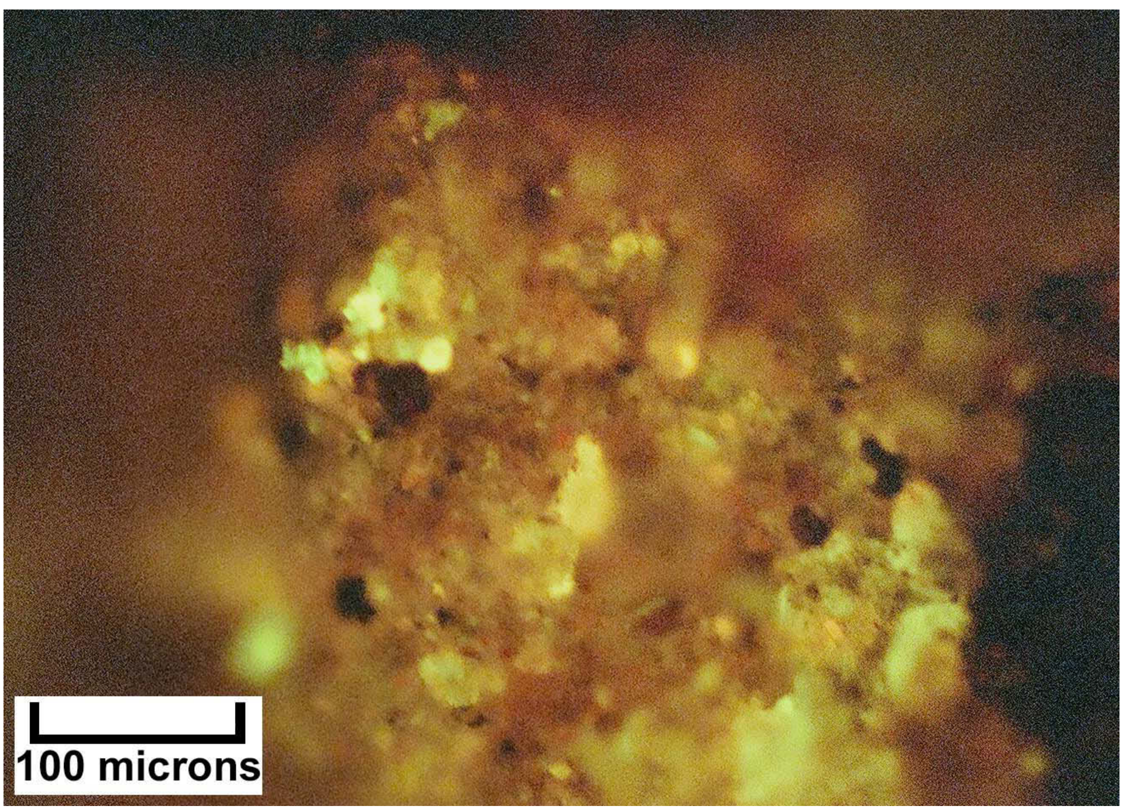
Binocular microscope image (wet) – Horsehead Unit #1 (Map #21), 6360-70 feet, C interval, peloidal, partially dolomitized organic shale.



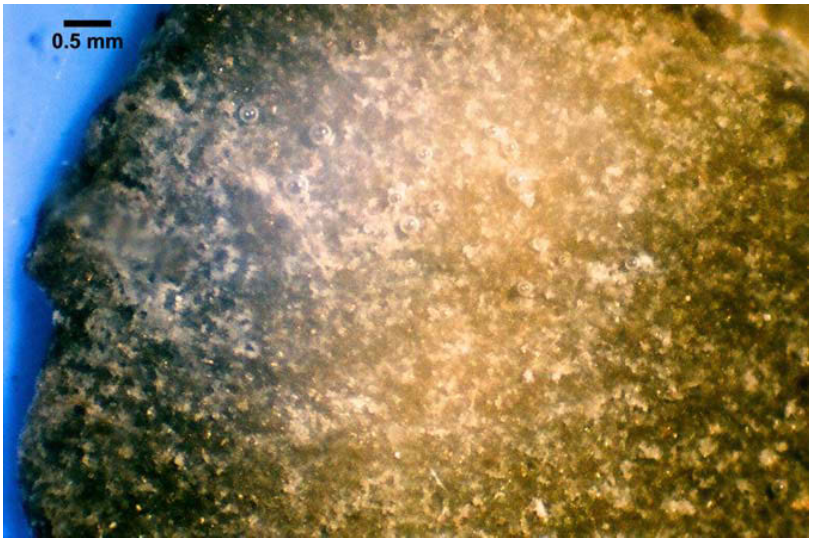
EF photomicrograph – Horsehead Unit #1 (Map #21), 6360-70 feet, C interval, 2.0 visual epifluorescence rating in mostly organic shale, slightly dolomitic.



Binocular microscope image (wet and etched) – Horsehead Unit #1 (Map #21), 6370-80 feet, C interval, microcrystalline brown dolomite with micropeloidal fabric.



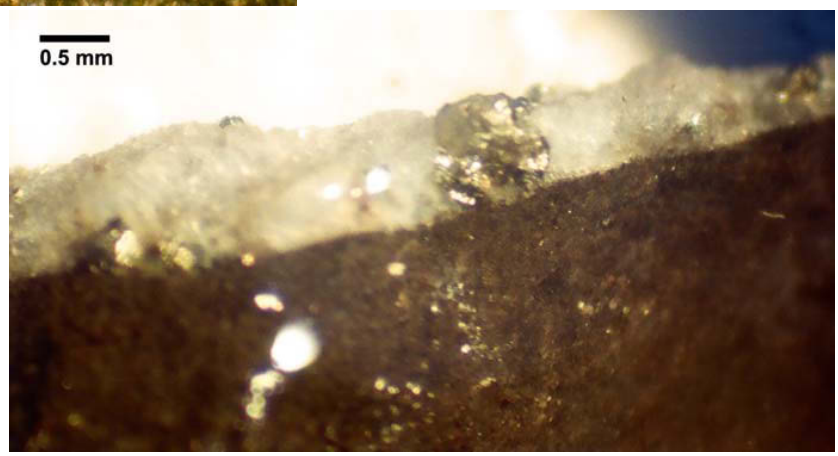
EF photomicrograph – Horsehead Unit #1 (Map #21), 6370-80 feet, C interval, 2.0 visual epifluorescence rating in shale and dolomitic shale.

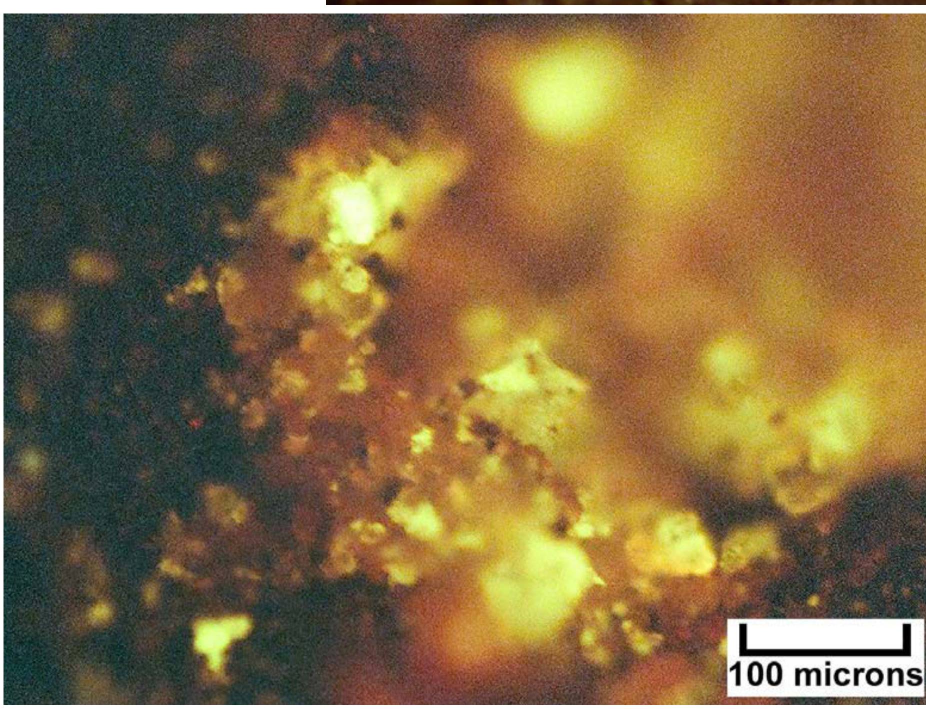


A

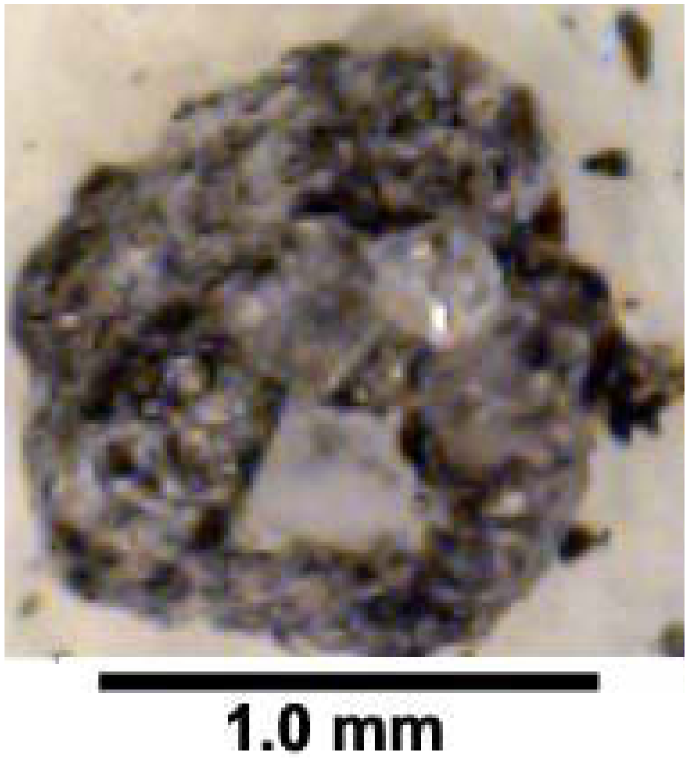
Binocular microscope images (A: dry, B: wet and etched) – Horsehead Unit #1 (Map #21), 6380-90 feet, C interval. A: overview of dolomitic shale matrix. B: close up of mineralized fracture.

B

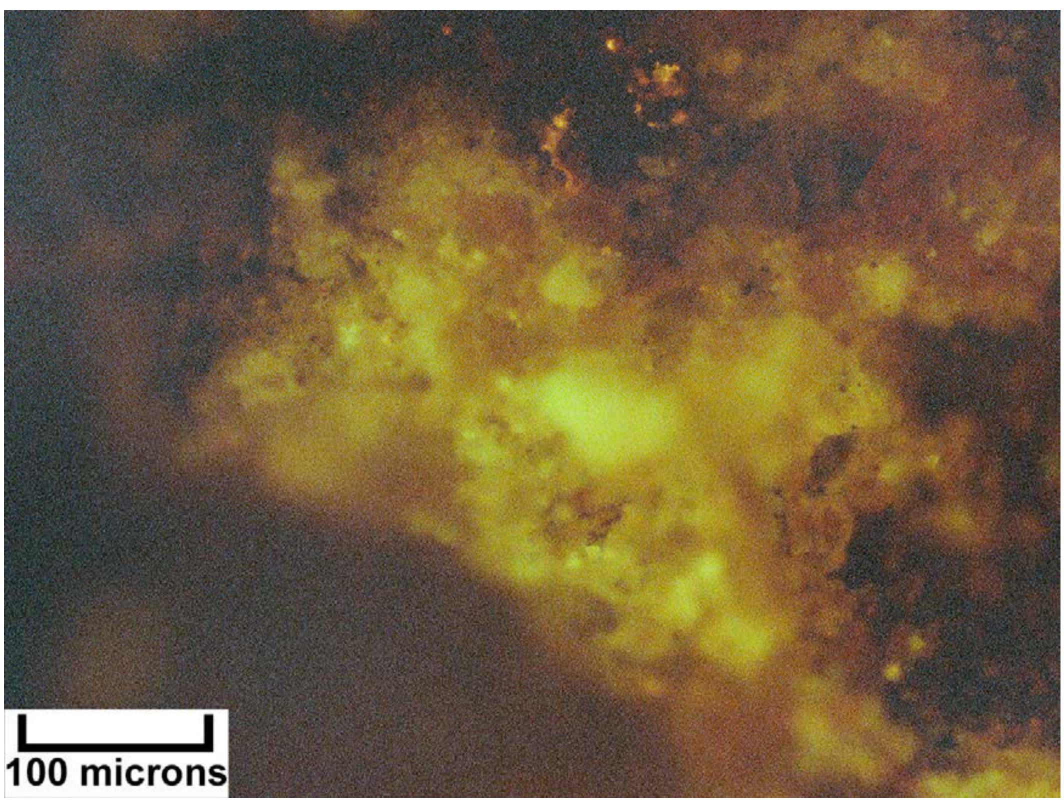




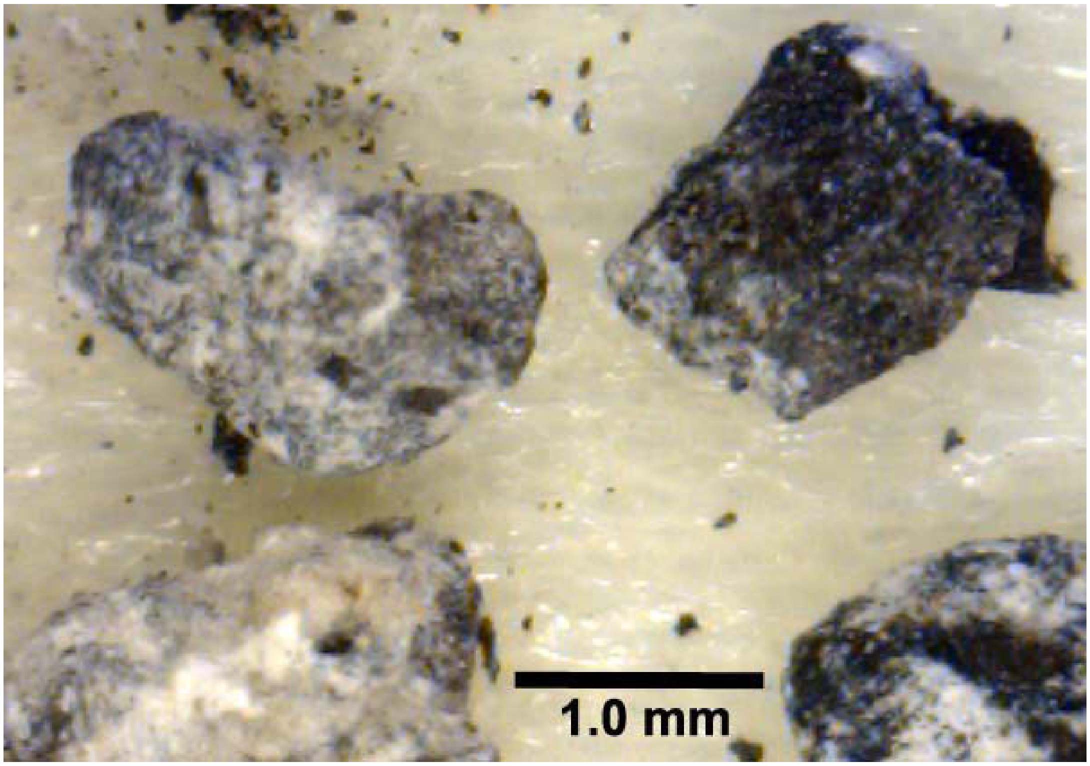
EF photomicrograph – Horsehead Unit #1 (Map #21), 6380-90 feet, C interval, 1.9 visual epifluorescence rating in shale and dolomitic shale.



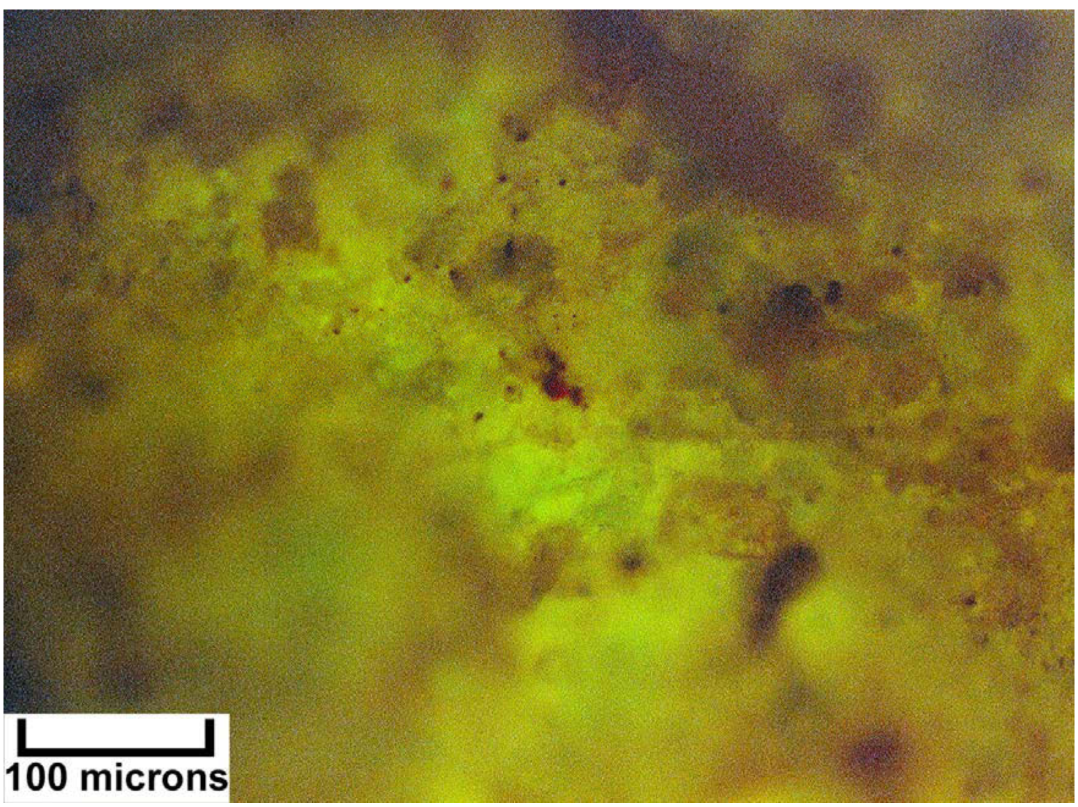
Digital microscope image (dry) – Hatch Point #1 (Map #22), 7220-30 feet, C interval, dolomite with black bitumen. Medium-sized euhedral crystals of dolomite (and possibly halite) are visible within a small representative cutting. The black bitumen is present within intercystalline pore spaces.



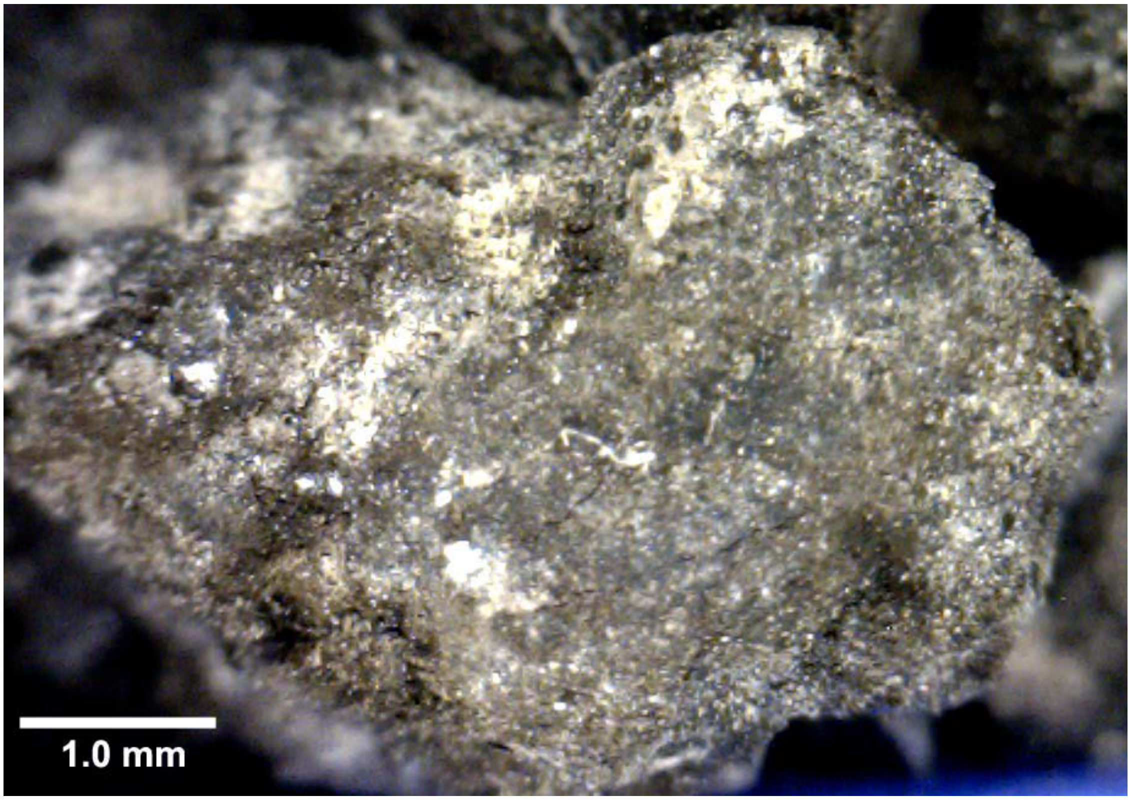
EF photomicrograph – Hatch Point #1 (Map #22), 7220-30 feet, C interval, 2.2 visual epifluorescence rating in rhombic dolomite clusters within black shale.



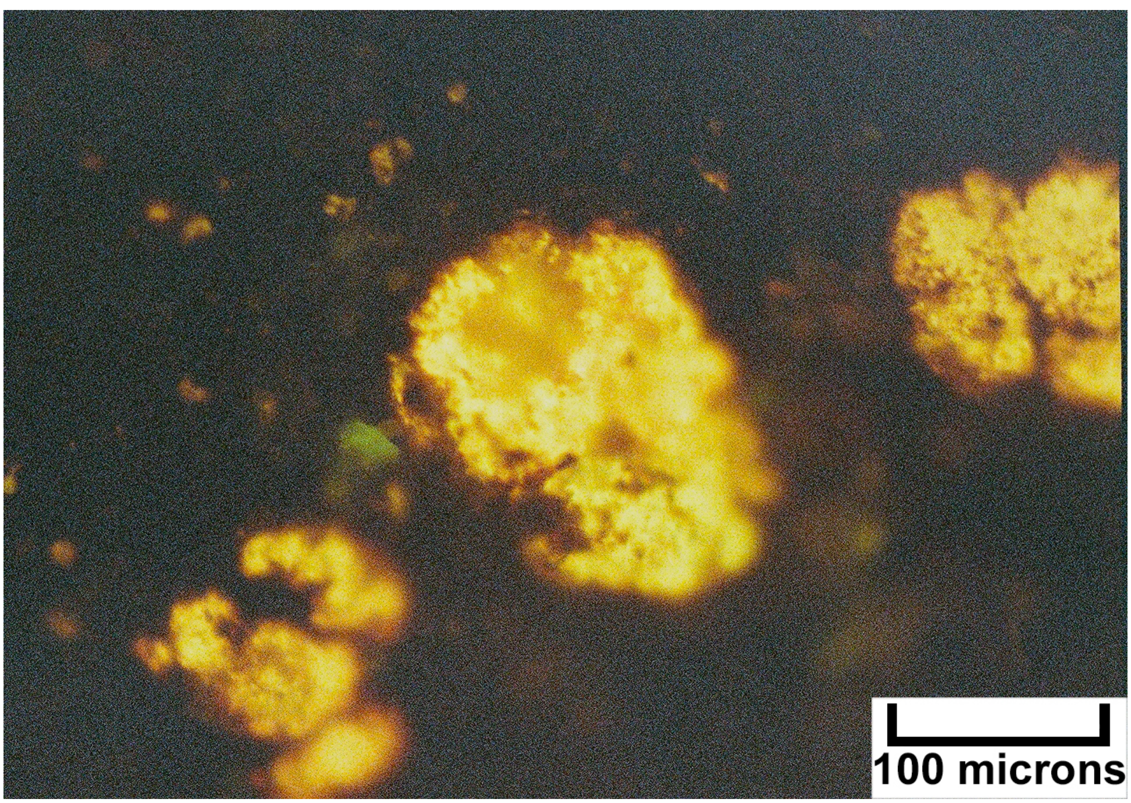
Digital microscope image (dry) – Hatch Point #1 (Map #22), 7260-70 feet, C interval, portions of four small cuttings that are composed of anhydritic dolomites with variable amounts of pore-filling black bitumen and some black argillaeous materials. Note the patches and hints of light to medium brown oil staining.



EF photomicrograph – Hatch Point #1 (Map #22), 7260-70 feet, C interval, 2.4 visual epifluorescence rating in microcrystalline dolomite in shale.

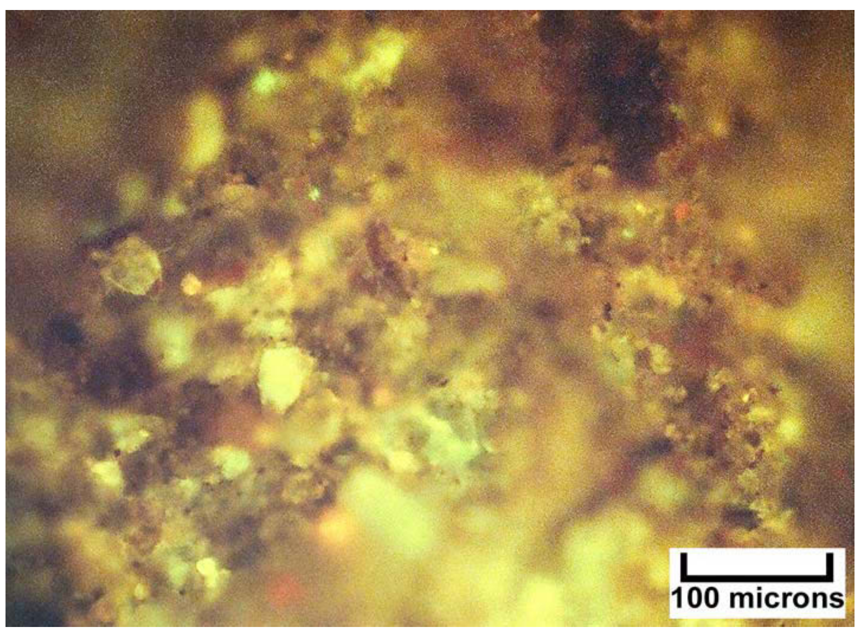


Digital microscope image (dry) – Threemile #12-7 (Map #23), 7650-70 feet (horizontal well), anhyditic dolomite. Generally low-porosity, finely crystalline dolomite with minor black bitumen within the limited intercrystalline pores.

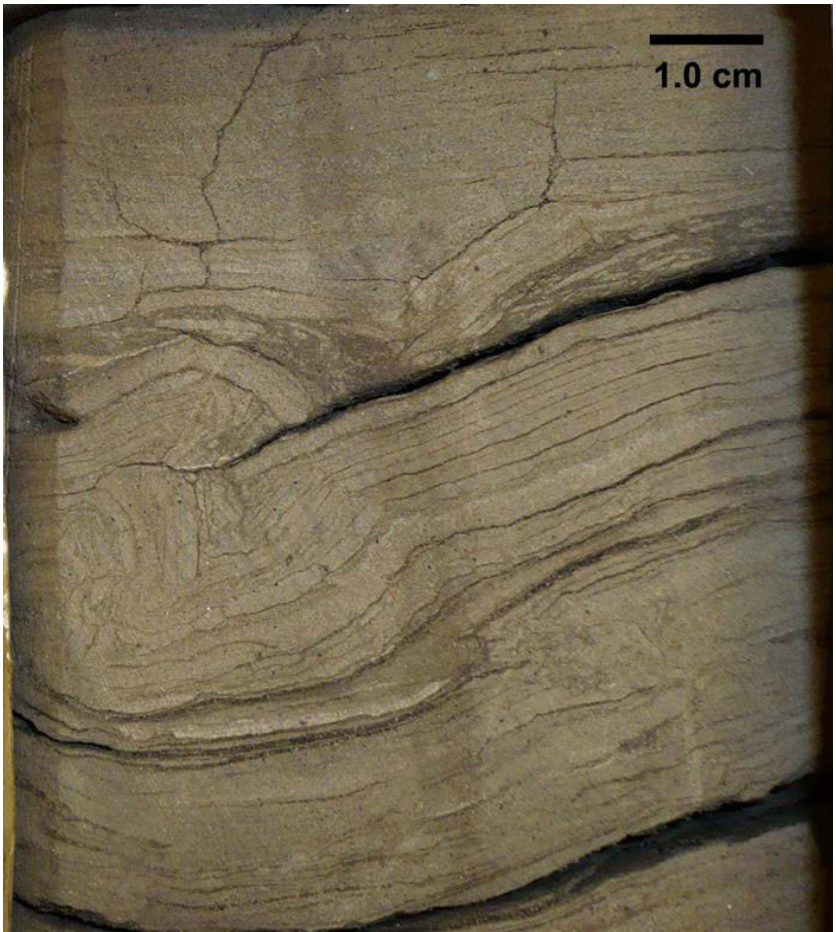


EF photomicrograph – Threemile #12-7 (Map #23), 7650-70 feet (horizontal well), 2.5 visual epifluorescence rating in very finely crystalline anhydritic dolomite.

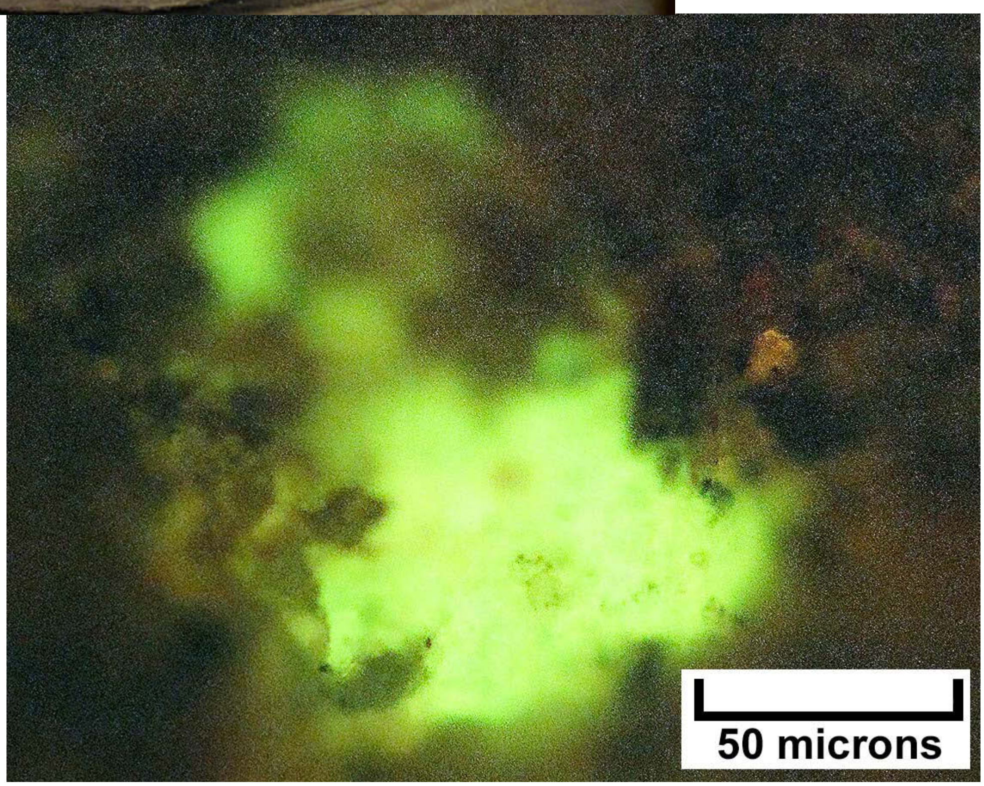
Close-up image (dry) of slabbed core – Gibson Dome #1 (Map 26), 5235-36 feet, A interval, anhydritic dolomite with light brown oil staining. Massive to laminated dolomite contains displacive nodules of white to light gray anhydrite. Small microbial "domes" or "biscuits" are present near the top of this core segment.



EF photomicrograph – Gibson Dome (Map #26), 5230-40 feet, A interval, 2.2 visual epifluorescence rating in fine to medium crystalline dolomite, packstone/grainstone with visible intercrystalline pores.

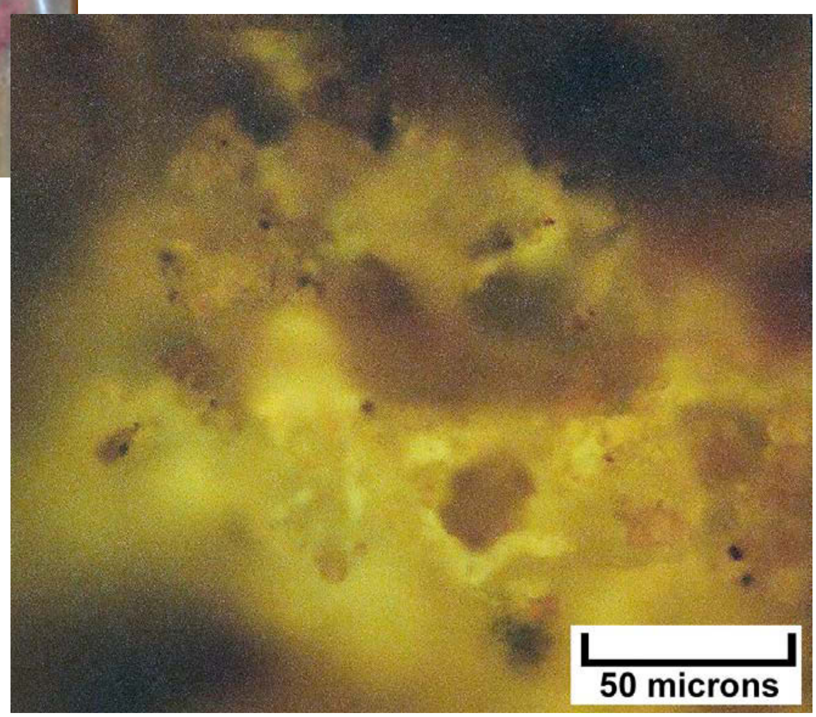


Close-up image (dry) of slabbed core – Gibson Dome #1 (Map #26), 5257.8 feet, B interval, silty dolomite with light brown oil staining. Laminated dolomites organized into undulatory thin beds which display early deformation or contortions. These laminites may be microbial in origin, and may be part of larger stromatolitic structures. Note the thin, angular rip-ups present in one dark brown, oil-stained layer within the laminites.



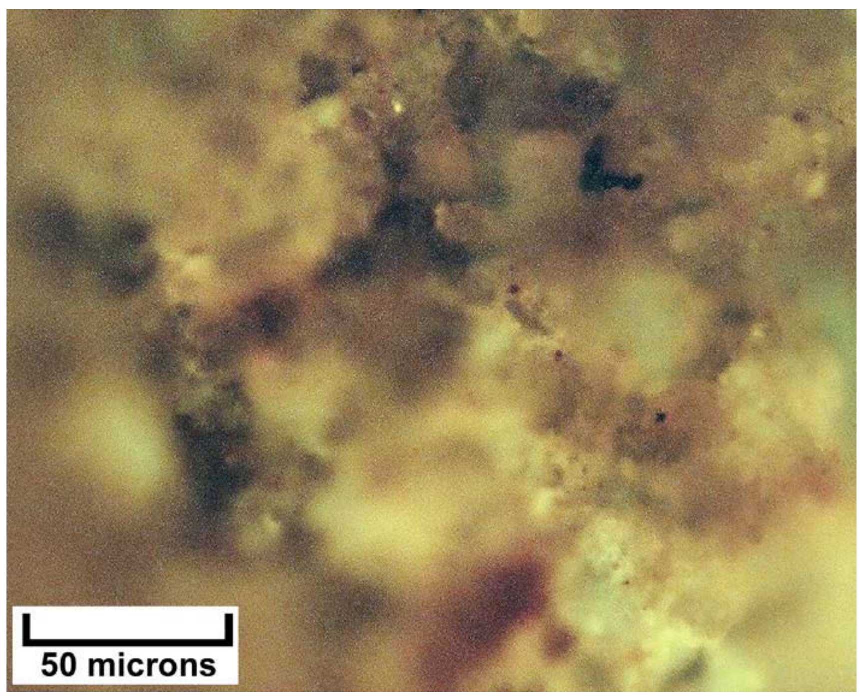
EF photomicrograph – Gibson Dome (Map #26), 5250-60 feet, B interval, 2.1 visual epifluorescence rating in well sorted siltstone with interparticle porosity and a few patches of dolomite.

Close-up image (wet) of slabbed core – Gibson Dome #1 (Map #26), 5260-61 feet, B interval, silty to argillaceous dolomites with light brown oil staining. Laminated silty dolomites with black clay-rich drapes are interbedded with thin black to dark gray organic-rich shales. Note the desiccation cracks and shallow burrows that interrupt the laminated dolomites.



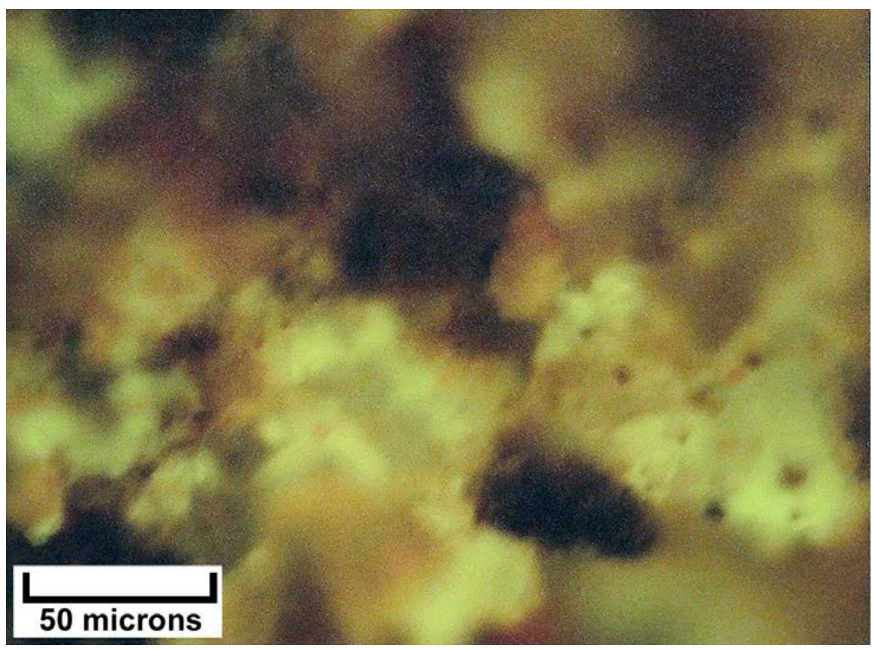
EF photomicrograph – Gibson Dome (Map #26), 5260-70 feet, B interval, 2.3 visual epifluorescence rating in partially cemented siltstone with remnant interparticle porosity and good fluorescence.

Close-up image (dry) of slabbed core – Gibson Dome #1 (Map #26), 5292-93 feet. C interval, calcareous dolomites with minor light brown oil staining. Generally massive to reworked grains and rip-up clasts alternate with well-laminated (microbial) beds.

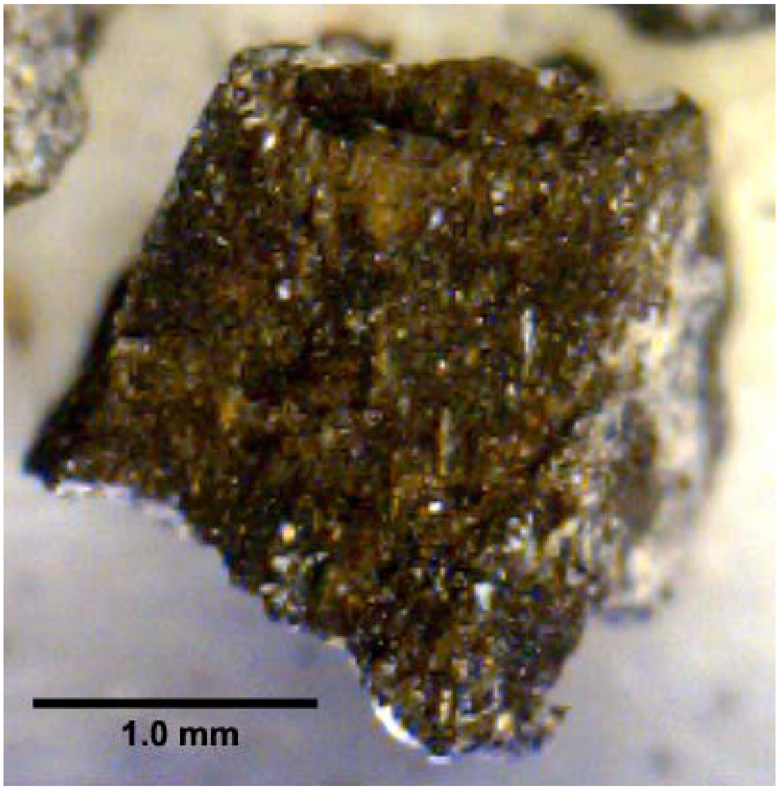


EF photomicrograph – Gibson Dome (Map #26), 5290-5300 feet, C interval, 2.0 visual epifluorescence rating in dolomitic grainstone, fine to very fine dolomite crystals, visible interparticle porosity.

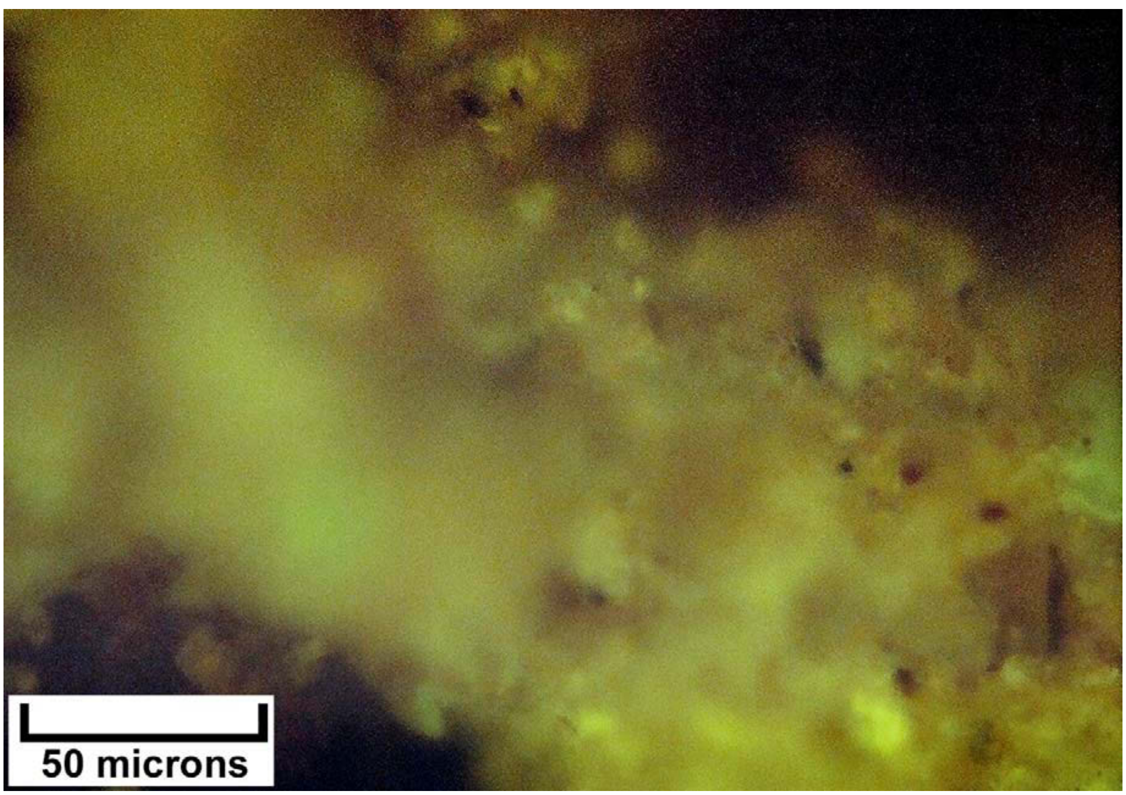
Close-up image (wet) of slabbed core – Gibson Dome #1 (Map #26), 5302-03 feet, C interval, dolomite with light to medium brown oil staining throughout alternating with very thin, organic black shale beds. The dolomites exhibit wavy laminated beds, consistent with a microbial origin.



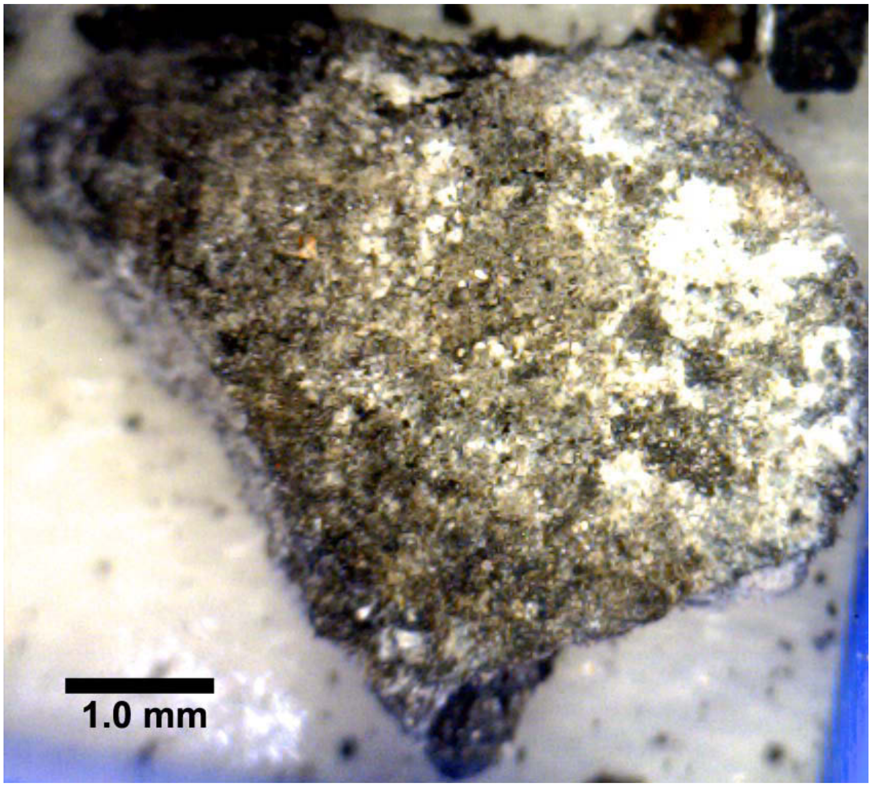
EF photomicrograph – Gibson Dome (Map #26), 5300-10 feet, C interval, 2.1 visual epifluorescence rating in dolomitic siltstone containing possible dolomitic grains and interparticle porosity.



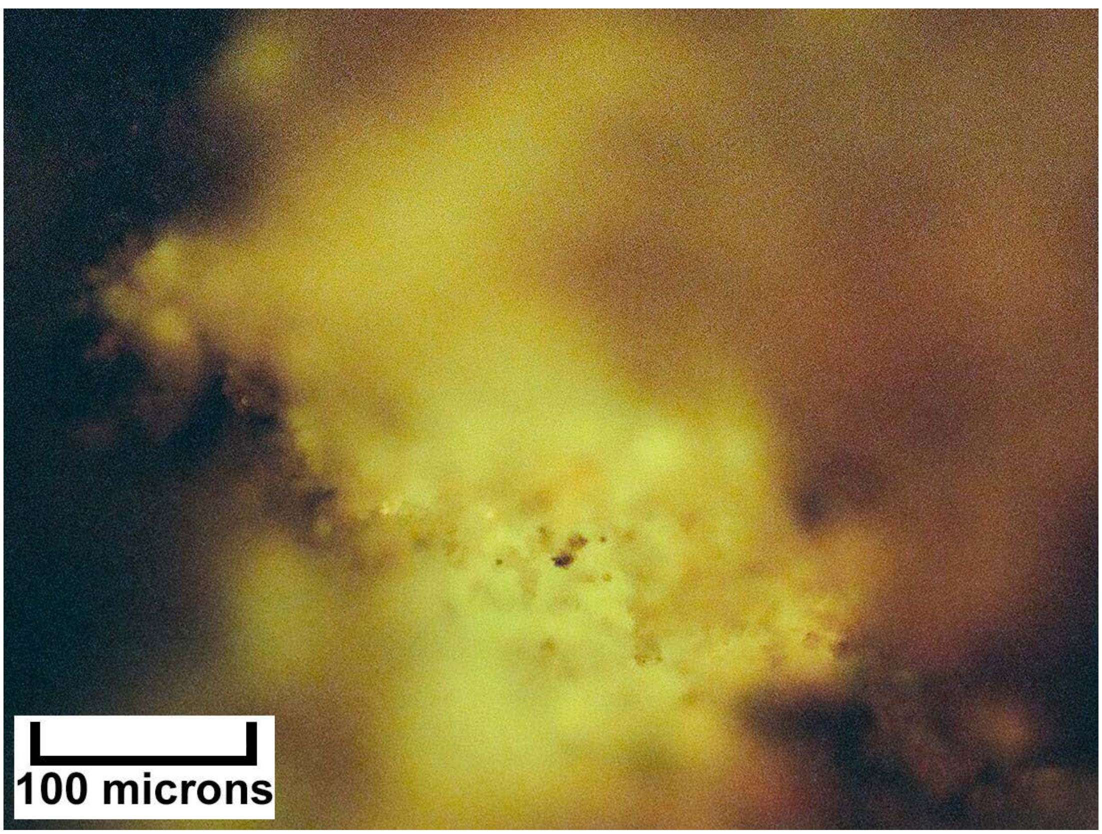
Digital microscope image (dry) – Hart Point Unit #1 (Map #28), 6780-90 feet, B interval, very silty dolomite with medium brown oil staining. Fine crystalline dolomite matrix with abundant silt grains. Note the numerous patches of black bitumen.



EF photomicrograph – Hart Point Federal #1 (Map #28), 6780-90 feet, B interval, 2.5 visual epifluorescence rating in patchy medium crystalline dolomite associated with small microbialite structures; good uniform fluorescence.

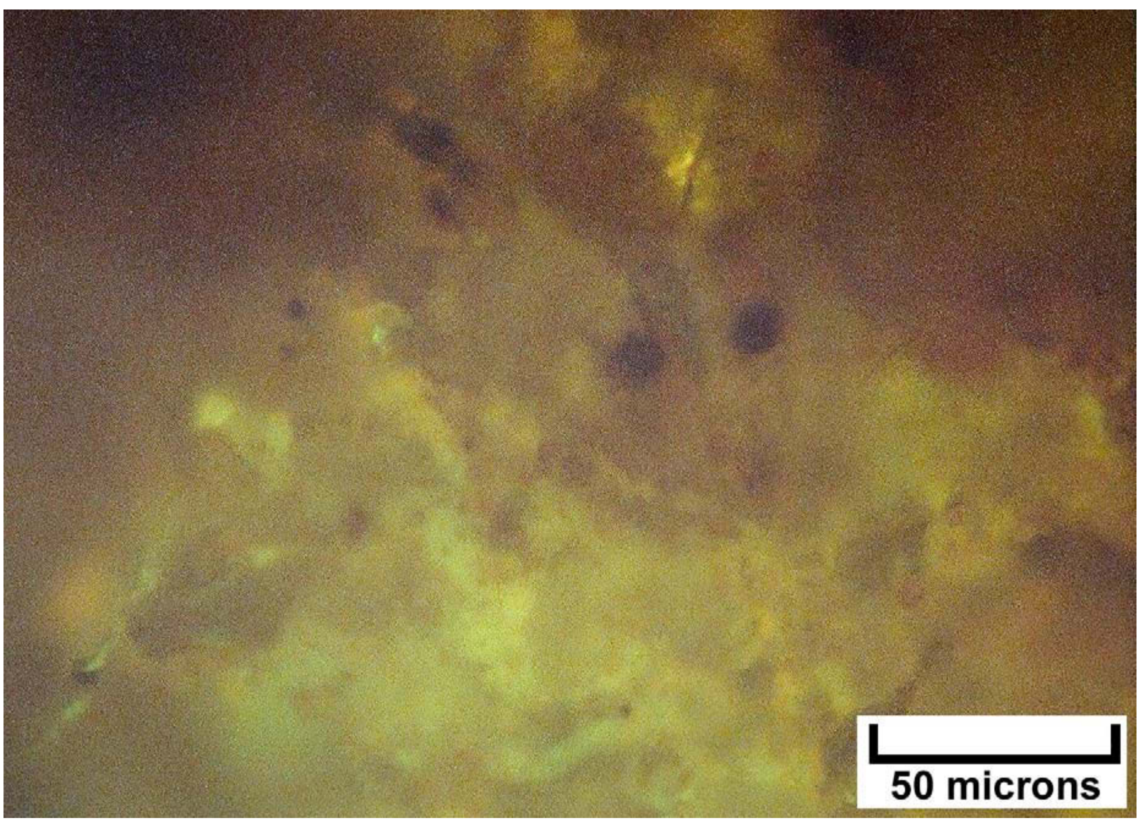


Digital microscope image (dry) – Hart Point Unit #1 (Map #28), 6810-20 feet, C interval, anhydritic (in white) and silty dolomite with only a hint of very light brown oil staining. Detrital silt-sized grains are visible within the dolomite matrix, while the anhydrite occurs in isolated white patches.

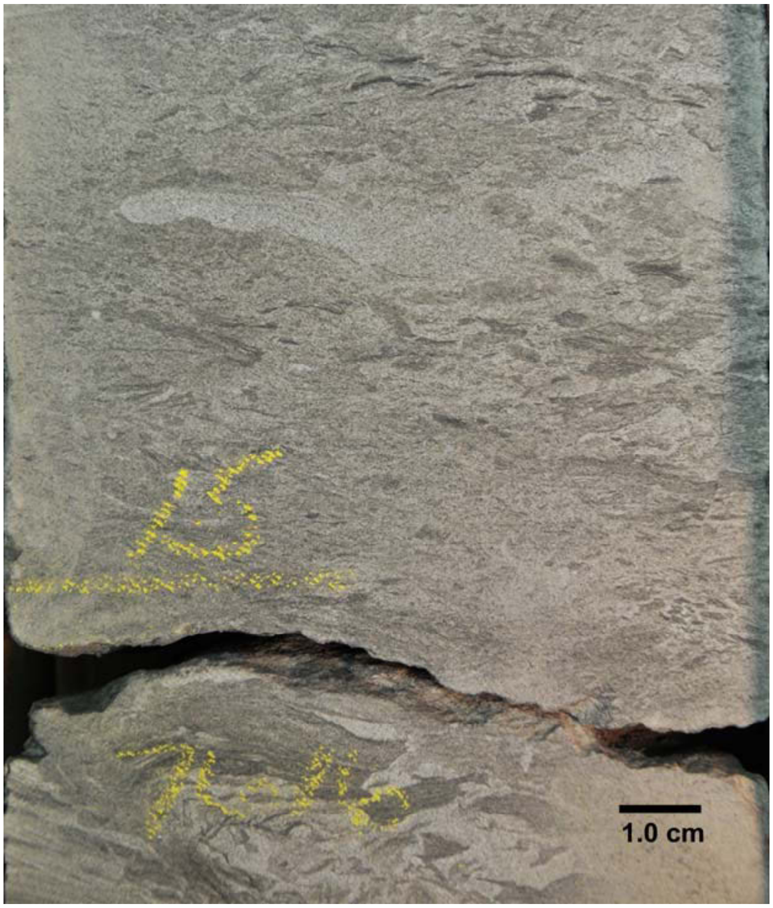


EF photomicrograph – Hart Point Federal #1 (Map #28), 6810-20 feet, C interval, 2.3 visual epifluorescence rating in patch of medium crystalline dolomite within tight, argillaceous matrix.

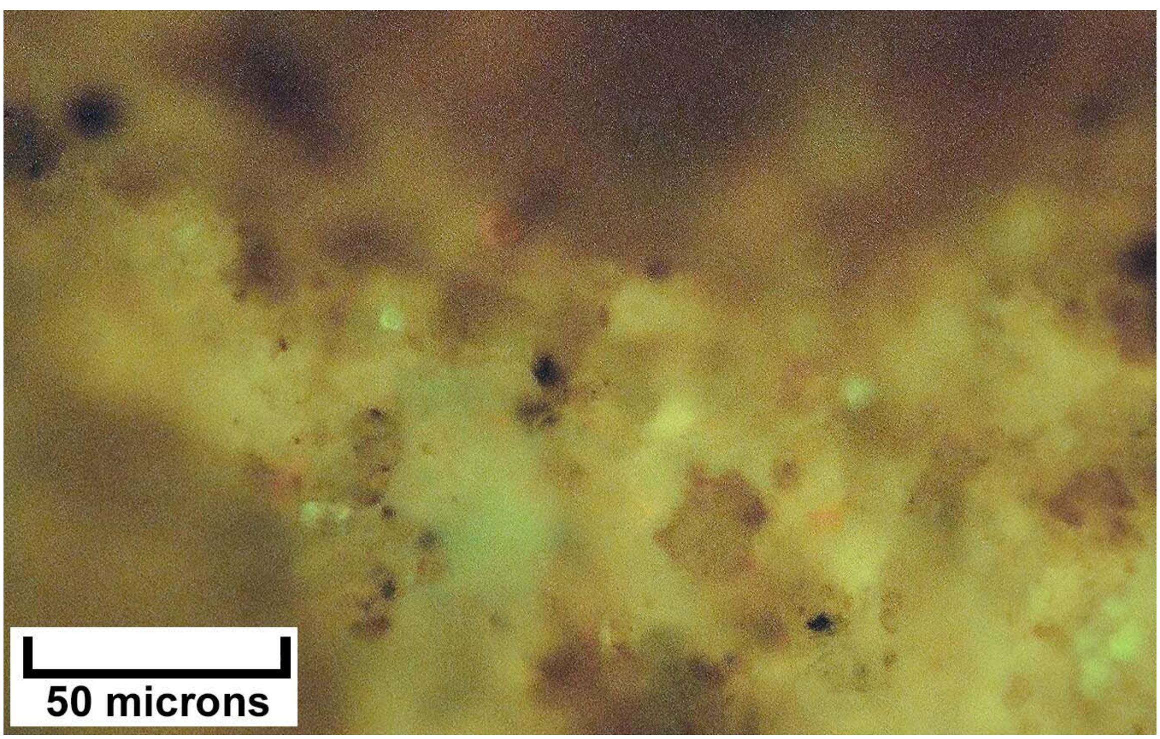
Close-up image (wet) of slabbed core – Cisco State #36-13 (Map #31), 7611.3 feet, B interval, dolomite with light brown oil staining. Rip-up clasts composed of laminated (stromatolitic?) microbialites with black bitumen lining intercrystalline pores within the dolomite matrix.



EF photomicrograph – Cisco State #36-13 (Map #31), 7611.3 feet, B interval, 2.5 visual epifluorescence rating in slightly silty medium crystalline dolomite with intercrystalline porosity, possible grainstone/packstone.

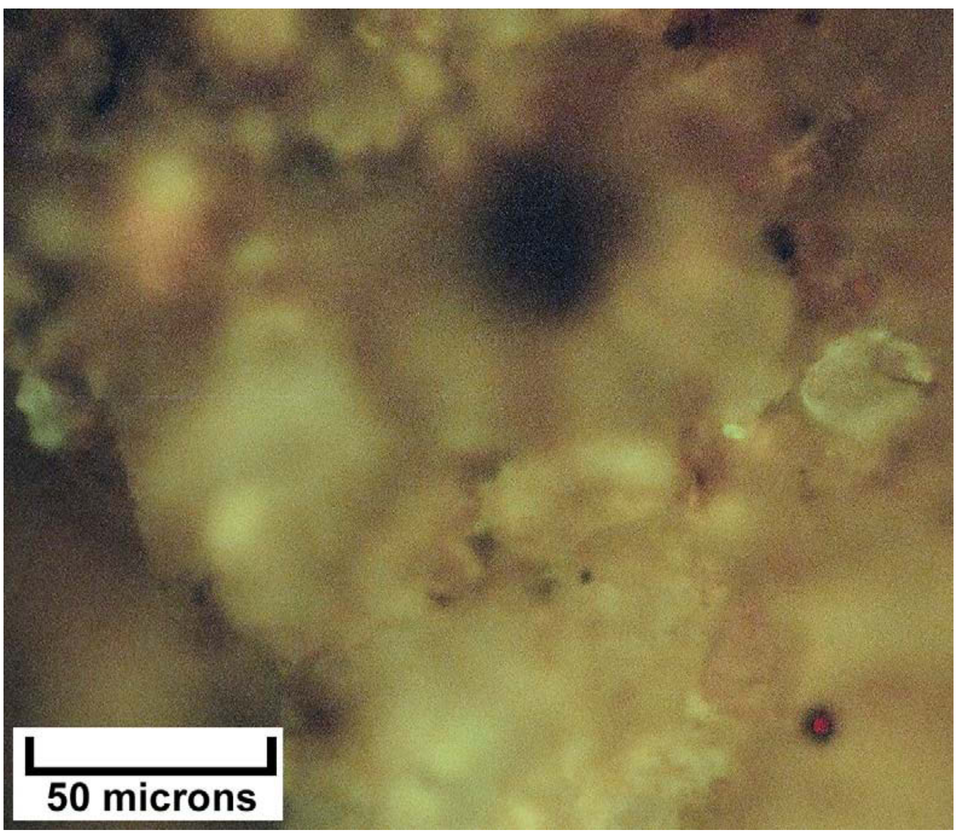


Close-up image (dry) of slabbed core – Cisco State #36-13 (Map #31), 7615.8 feet, B interval, silty dolomite consisting of rip-up clasts composed of laminated (stromatolitic?) microbialites with black bitumen lining intercrystalline pores within the dolomite matrix. Sediment-filled burrows are also present.



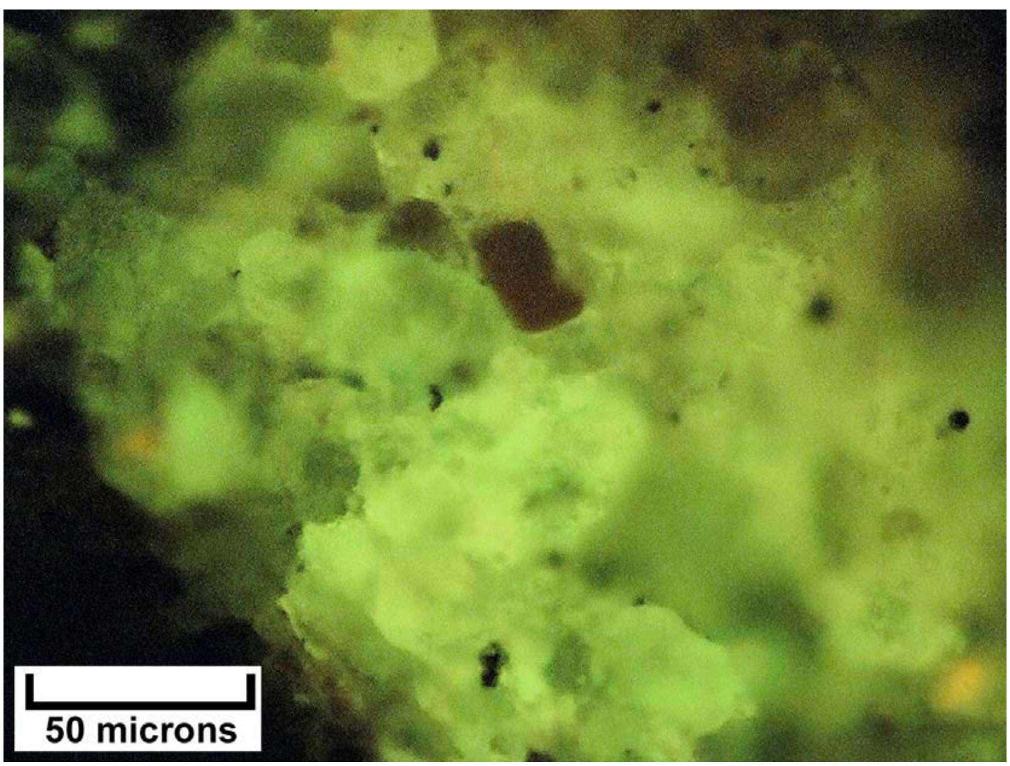
EF photomicrograph – Cisco State #36-13 (Map #31), 7615.8 feet, B interval, 2.6 visual epifluorescence rating in fine to medium crystalline dolomite with patchy good fluorescence and visible pores, packstone/grainstone(?).

Close-up image (wet) of slabbed core – Cisco State #36-13 (Map #31), 7619.3 feet, B interval, dolomite with patchy light brown oil staining. Wavy stromatolitic laminae are occasionally draped with argillaceous layers. Black bitumen is present within some of the intercrystalline pores.



EF photomicrograph – Cisco State #36-13 (Map #31), 7619.3 feet, B interval, 2.3 visual epifluorescence rating in slightly silty dolomite, packstone/grainstone with fair to good intercrystalline porosity.

Close-up image (wet) of slabbed core – Cisco State #36-13 (Map #31), 7623.1 feet, B interval, silty to slightly argillceous dolomite composed of an interval of wavy laminae (stromatolitic?) overlain by dolomitized skeletal and non-skeletal coated grains. Note the black patches of bitumen that are concentrated within matrix porosity.



EF photomicrograph – Cisco State #36-13 (Map #31), 7623.1 feet, B interval, 2.8 visual epifluorescence rating in slightly dolomitic siltstone, moderately well sorted with bright fluorescence in interparticle porosity.