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THE CHATTANOOGA SHALE (DEVONIAN AND MISSISSIPPIAN)
FROM THE TENNESSEE DIVISION OF GEOLOGY-
U.S. DEPARTMENT OF ENERGY CORED DRILL HOLES
NUMBER 4 and 5, HAWKINS COUNTY, TENNESSEE

by

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The Chattanooga Shale (Devonian and Mississippian)
from the Tennessee Division of Geology-
U.S. Department of Energy cored drill holes
number 4 and 5, Hawkins County, Tennessee

by

John B. Roen,¹ Laure G. Wallace,¹
and Robert C. Milici²

INTRODUCTION

The Tennessee Division of Geology under contract to the Morgantown Energy Technology Center of the U.S. Department of Energy has drilled eight NX coreholes in eastern Tennessee. The coring program, under the supervision of R. C. Milici, was designed to retrieve continuous cores for a detailed study of the character of the Chattanooga Shale. The geophysical wire-line logging of the NX drill holes was performed by the U.S. Geological Survey. The lithologic descriptions of the cores were prepared by Wallace and Milici.

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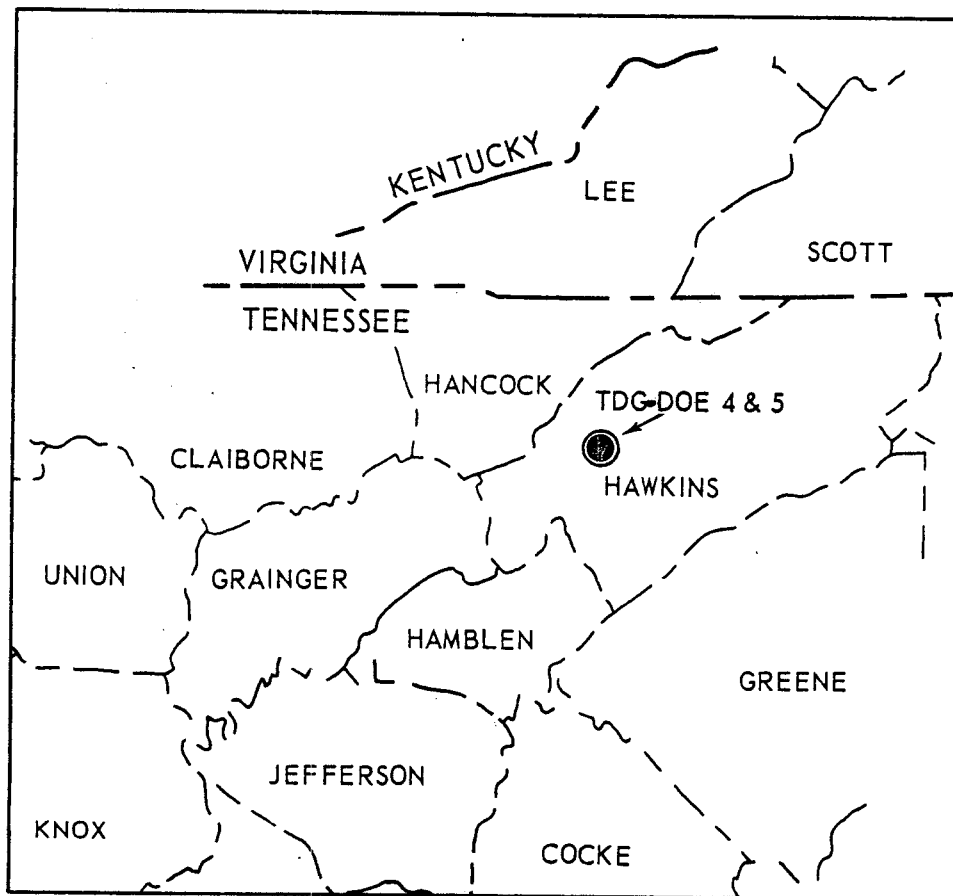
² Tennessee Division of Geology; present affiliation, State Geologist, Division of Mineral Resources, Commonwealth of Virginia

The lithologic and wire-line log data in conjunction with two seismic surveys conducted by Geophysical Service, Inc., for the Tennessee Division of Geology and the U.S. Department of Energy will be used to evaluate the hydrocarbon potential of the Chattanooga Shale in northeastern Tennessee.

The purpose of this report is to present a detailed lithologic description and gamma-ray log of the Tennessee Division of Geology and U.S. Department of Energy cored drill holes no. 4 and 5 (TDG-DOE no. 4 and no. 5). Reports on the cores from TDG-DOE no. 1 and 2 and TDG-DOE no. 3 drill holes have been published by Roen and others (1980a, 1980b).

TDG-DOE no. 4 corehole, Tennessee State coordinates 761, 500 N; 2,855,050 E, is located on the Anthony Lucas property in the Pressmans Home 7 1/2-minute quadrangle, Hawkins County, Tennessee (Fig. 1). The hole was spudded in the Chattanooga Shale at ground elevation 1245 ft, and coring was continuous to a total depth of 1525.1 ft. The base of the Chattanooga was penetrated at a depth of 1499.0 ft. Approximately 26 ft of the underlying Wildcat Valley Sandstone(?) was cored. To obtain a complete section of the Chattanooga, the drilling rig was moved south to another site, TDG-DOE no. 5, in the overlying Grainger Formation. About 205 ft of Chattanooga Shale was recovered, including the upper contact. TDG-DOE no. 5 corehole, also on the Lucas property in the Pressmans Home quadrangle, was spudded at the ground elevation of 1350 ft. The Tennessee State coordinates are 759,000 N, 2,855,900 E.

In spite of the overlap, no distinct marker beds were found to facilitate a positive correlation between the two cores. Reconstruction of the total Chattanooga section was based on detailed field mapping of the uppermost dark-gray shale below the base of the Grainger Formation and the projection of the beds. The total thickness of the Chattanooga Shale at the coring locations is estimated to be 1650 - 1700 ft.



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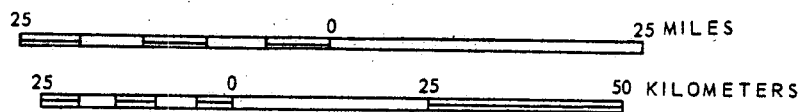


Figure 1.--Index map showing location of cored drill holes.

GEOLOGIC SETTING

The coring sites are approximately in the central part of the Appalachian Valley and Ridge province (Fig. 2), a tectonic region of folds and imbricate thrust faults in rocks of Paleozoic age. The coreholes are near the contact of the Chattanooga Shale and the Grainger Formation on Pine Mountain on the northwestern limb of the Greendale syncline. The southeast limb of the syncline has been truncated and thrust northwestward towards the fold axis by the Saltville thrust fault system. The Chattanooga Shale unconformably overlies the Lower Devonian Wildcat Valley Sandstone(?). Above the Chattanooga are the shales and very fine grained sandstones of the Lower Mississippian Grainger Formation.

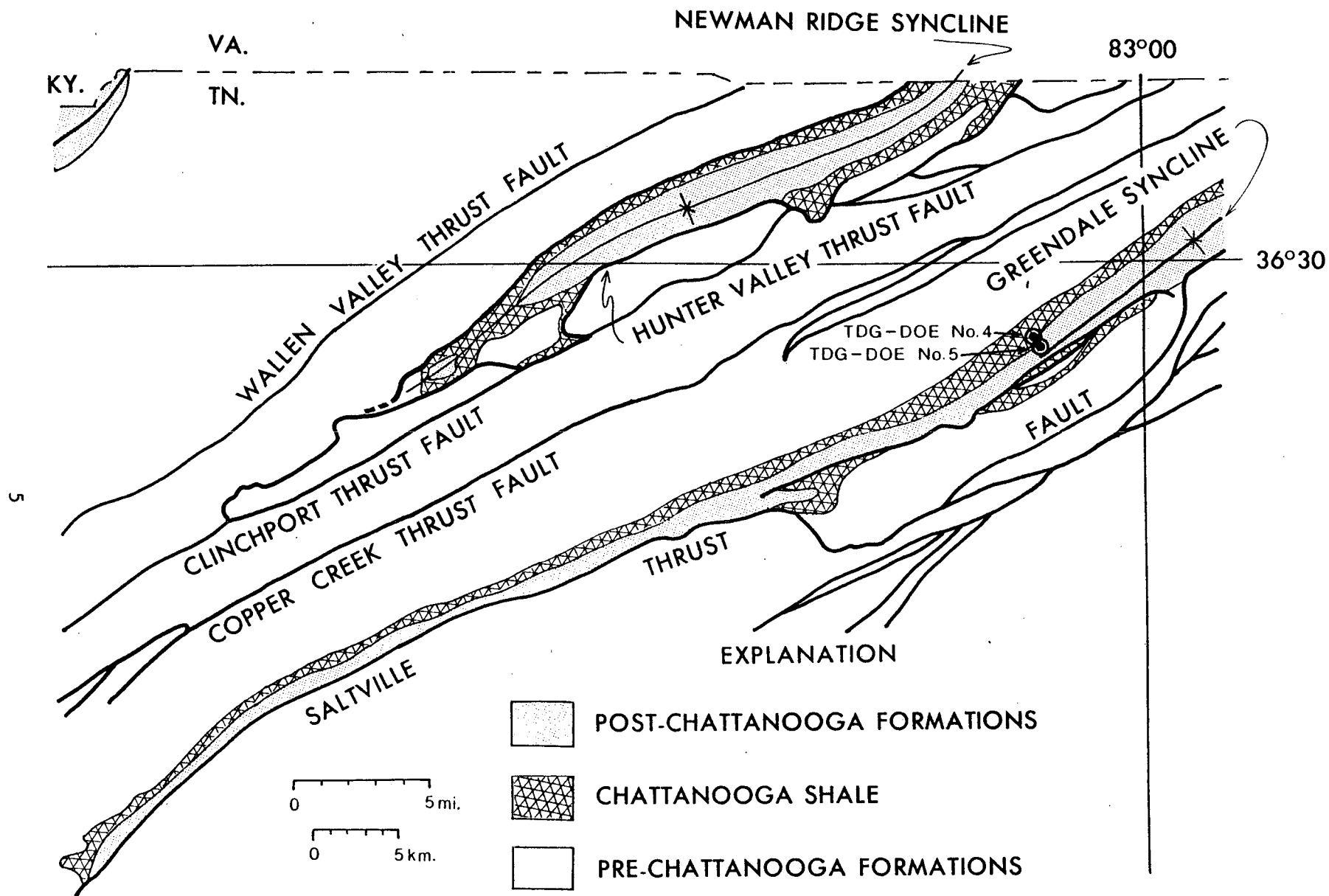


Figure 2.— Generalized geologic map showing the locations of TDG-DOE cored drill holes No. 4 and No. 5. Modified from Swingle and others (1966).

LITHOLOGIC DESCRIPTION

TDG-DOE CORED DRILL HOLE NO. 4

Chattanooga Shale

Depth (ft)¹

0 to 9.5	Casing, no core recovered.
9.5 to 96.3	Shale, very silty, medium olive-gray (5 Y 3/1) ² to olive-gray (5 Y 4/1), laminated to thinly laminated, hard, brittle. Contains siltstone, in part calcareous, beds range from 0.005 to 0.1 ft in thickness. Siltstone beds at 33.8, 52.2, 55.2, 57.0, 64.7, 67.6, 72.1, 79.0, 88.4, and 95.6 ft. Siltstone increases toward base of section. Unit is highly broken and fractured from 67.7 to 77.2 ft. Calcite-filled fault trace at 88.5 ft. <u>Tasmanites</u> and very finely crystalline pyrite disseminated throughout.
96.3 to 98.8	Shale, very silty, medium olive-gray (5 Y 3/1) to olive-gray (5 Y 4/1), laminated to thinly laminated, hard, brittle. Siltstone laminae range from 0.005 to 0.01 ft in thickness and compose about 20 percent of unit. Contain disseminated very finely crystalline pyrite spheres.
98.8 to 117.4	Siltstone shaly, medium olive-gray (5Y 3/1) to olive-gray (5 Y 4/1), laminated, very hard, containing discrete light olive-gray (5 Y 5/2) siltstone bed as much as 0.01 ft thick. Contains siltstone, rip-up or flow clasts.

1 Measured in feet, meters not applicable.

2 Color symbols are those of Goddard and others (1948).

- 117.4 to 159.0 Siltstone, shaly, medium olive-gray (5 Y 3/1) to olive-gray (5 Y 4/1), thinly laminated, hard. Contains light olive-gray (5 Y 5/2) siltstone laminae as much as 0.005 ft thick. Intensely fractured and slickensided from 128.4 to 128.8 ft; below this zone, unit becomes a shaly siltstone, very hard, many slickensides. Intensely fractured at 132.5 ft. Folded and faulted near base of unit.
- 159.0 to 161.7 Siltstone, shaly, medium olive-gray (5 Y 3/1) to olive-gray (5 Y 4/1), very hard. Massive-bedded, no distinct siltstone laminae.
- 161.7 to 191.5 Siltstone, shaly, medium olive-gray (5 Y 3/1) to olive-gray (5 Y 4/1), very hard, thinly laminated. Contains light olive-gray (5 Y 5/2) siltstone laminae as much as 0.005 ft thick. Light olive-gray (5 Y 5/2) siltstone laminae decrease toward base of section. Folded, fractured, and slickensided from 164.8 to 167.0 ft.
- 191.5 to 193.0 Shale, silty, medium olive-gray (5 Y 3/1) to olive-gray (5 Y 4/1), intensely fractured and slickensided.
- 193.0 to 245.3 Siltstone, shaly, dark olive-gray (5 Y 3/1) to olive-gray (5 Y 4/1), hard, thinly laminated to laminated; interbedded with 20 - 30 percent light olive-gray (5 Y 5/2) siltstone laminae ranging from 0.005 to 0.05 ft in thickness. Locally shaly siltstone beds as much as 0.1 ft thick are iron stained. Folded, faulted, and slickensided.

- Intensely fractured and slickensided zone from 225.3 to 227.0 ft.
- 245.3 to 274.7 Siltstone, shaly, dark olive-gray (5 Y 3/1) to olive-gray (5 Y 4/1) hard, thinly laminated; interbedded with 10-15 percent light-olive-gray (5 Y 5/2) siltstone laminae. Contains folds and calcite-filled fractures.
- 274.7 to 292.0 Siltstone, olive-gray (5 Y 4/1), laminated, hard, interbedded with 30 percent laminated shaly siltstone, dark olive-gray (5 Y 3/1) to olive-black (5 Y 2/1). Contains flow rolls and calcite-filled fractures slickensided.
- 292.0 to 294.0 Siltstone, shaly, dark-olive-gray (5 Y 3/1) to olive-gray (5 Y 4/1), hard, thinly laminated; interbedded with 25 percent discrete siltstone beds. Faults, burrow fillings.
- 294.0 to 298.0 Siltstone, shaly, dark-olive-gray (5 Y 3/1) to olive-gray (5 Y 4/1). Intensely fractured and slickensided.
- 298.0 to 302.5 Siltstone, olive-gray (5 Y 4/1), hard, interbedded with 30 percent shaly siltstone, dark-olive-gray (5 Y 3/1) to olive-black (5 Y 2/1), laminated.
- 302.5 to 311.4 Siltstone, shaly, olive-black (5 Y 2/1), hard, laminae as much as 0.005 ft thick. Discrete light olive-gray (5 Y 5/2) siltstone beds as much as 0.005 ft thick compose 15 - 20 percent of the unit. Faulted, folded, flow rolls.

- 311.4 to 318.2 Siltstone, olive-gray (5 Y 4/1), hard; interbedded with 30 percent shaly siltstone, dark-olive-gray (5 Y 3/1) to olive-black (5 Y 2/1), laminated.
- 318.2 to 320.9 Shale, silty, olive-black (5 Y 2/1), thick bedded, hard. Most surfaces slickensided.
- 320.9 to 324.0 Siltstone, olive-gray (5 Y 4/1), laminated, hard; interbedded with 30 percent shaly siltstone, dark olive-gray (5 Y 3/1) to olive-black (5 Y 2/1), laminated.
- 324.0 to 387.3 Shale, brownish-black (5 YR 2/1), platy-bedded; interbedded with 50 percent siltstone, olive-gray (5 Y 4/1) in beds as much as 0.05 ft thick, hard. Folding, faulting, intensely fractured locally. Contains Tasmanites and conodonts. Foerstia at 325.4 ft.
- 387.3 to 401.6 Shale, slightly silty, grayish-black (N 2) to brownish-black (5 YR 2/1), very thin bedded to platy-bedded; interbedded with 30 percent siltstone, olive-gray (5 Y 4/1) in beds as much as 0.1 ft thick. Grayish-black shale is interbedded with 15 percent dark olive-gray shale (5 Y 3/1) in beds as much as 0.2 ft thick. Fractured zone at 395.1 ft. Abundant Tasmanites and pyrite spheres.

- 401.6 to 404.0 Shale, grayish-black (N 2) to brownish-black (5 YR 2/1) interbedded with 35 percent dark olive-gray shale (5 Y 3/1); thin-bedded. Tasmanites and pyrite spheres.
- 404.0 to 431.5 Shale, slightly silty, grayish-black (N 2) to brownish-black (5 YR 2/1), very thin bedded to platy bedded; interbedded with 30 percent siltstone, olive-gray (5 Y 4/1), in beds as much as 0.01 ft thick. Grayish-black shale is interbedded with 15 percent dark-olive-gray shale (5 Y 3/1) in beds as much as 0.2 ft thick.
- 431.5 to 435.5 Shale, olive-gray (5 Y 4/1), interbedded with 40 percent shale, olive-black (5 Y 2/1).
- 435.5 to 441.8 Shale, olive-gray (5 Y 4/1) to olive-black (5 Y 2/1), intensely fractured and slickensided.
- 441.8 to 449.2 Shale, grayish-black (N2) to brownish-black (5 YR 2/1), very thin bedded to platy-bedded, interbedded with 20 percent shale, olive-black (5 Y 2/1). A few siltstone laminae commonly less than 0.005 ft thick but as much as 0.03 ft thick.
- 449.2 to 451.3 Shale, grayish-black (N 2) to brownish-black (5 YR 2/1) interbedded with 50 percent olive-black (5 Y 2/1) shale beds as much as 0.5 ft thick. Pyrite spheres, Tasmanites.
- 451.3 to 452.0 Shale, black (N 1) containing a 0.3-ft-thick dark olive-gray (5 Y 3/1) bed in the middle. Intensely fractured at the base.

- 452.0 to 502.5 Shale, olive-gray (5 Y 4/1), brittle, interbedded with 35 percent shale, olive-black (5 Y 2/1) to brownish-black (5 YR 2/1). Siltstone beds as much as 0.1 ft thick from 477 to 477.1 ft, 477.4 to 477.5 ft, and at 489.5 and 490.0 ft. Fractured and slickensided; more intense toward base of section.
- 502.5 to 522.9 Shale, slightly silty, black (N 1) to grayish-black (N 2), hard. Calcite-filled fractures, pyrite spheres, Tasmanites.
- 522.9 to 599.3 Shale, olive-gray (5 Y 4/1), thin-bedded to very thick bedded; interbedded with 30 percent grayish-black (N 2) shale, thin- to thick-bedded. Predominantly olive-gray (5 Y 4/1) shale from 530 to 531.8, 532.1 to 533.3, 534.7 to 538.2, 538.6 to 545.8, 546.2 to 547.5, 560.9 to 562.8, 564.1 to 567.4, 567.7 to 570.3, 571.6 to 574.6, 574.8 to 577.1, 584.3 to 585.5, 585.7 to 588, and 595.5 to 597.0 ft. Predominantly grayish-black (N 2) shale from 525.9 to 527.3, 552.7 to 554.1, 554.2 to 555.3, 578 to 579.4, 579.9 to 582.4, 588.6 to 589.8, 590.8 to 592.0, 592.1 to 593.1, and 594.1 to 595.5 ft. A few siltstone laminae from 560.9 to 571.6 ft. Intensely fractured from 548.3 to 548.7 ft. Tasmanites and pyrite nodules.
- 599.3 to 631.5 Shale, grayish-black (N 2), interbedded with 30 percent olive-gray (5 Y 4/1), shale, thin- to thick-bedded.

Predominantly grayish-black (N 2) shale from 603 to 605.1, 606.0 to 608.0, 617.3 to 618.7, and 622.7 to 624.4 ft. Predominantly olive-gray shale (5 Y 9/1) from 624.6 to 627.0 and 628.6 and 630.7 ft. Intensely fractured from 606.0 to 608.0, 610.1 to 611.0, 612.8 to 613.6, 614.7 to 615.7, and 624.6 to 627.0 ft.

Conodonts and pyrite nodules.

631.5 to 633.0

Limestone, grayish-olive (10 Y 4/2) and olive-gray (5 Y 3/2).

633.0 to 633.7

Shale, grayish-black (N 2), interbedded with 40 percent olive-gray (5 Y 4/1) shale. Grayish-black (N 2) shale is highly slickensided.

633.7 to 708.6

Shale, grayish-black (N 2) to black (N 1), interbedded with 10 percent olive-gray (5 Y 4/1) and dark-olive-gray (5 Y 3/1) shale. Olive-gray shale from 637.0 to 637.1, 639.9 to 640.1, 641.1 to 641.3, 641.8 to 642.0, 645.9 to 646.3, 652.6 to 653.1, 655.0 to 655.6, 656.0 to 656.3, 660.0 to 660.1, 661.1 to 661.4, 663.6 to 664.7, 675.5 to 675.7, 689.0 to 689.9, 690.6 to 692.5, 694.0 to 694.5, and 697.3 to 698.1 ft. Tasmanites, conodonts, pyrite nodules, a few siltstone laminae as much as 0.005 ft thick. Fractured and slickensided; more intense in the lower third of the unit.

708.6 to 726.5

Shale, grayish-black (N 2), interbedded with 40 percent dark olive-gray (5 Y 3/1) shale, medium- to very

thick bedded. Predominantly grayish-black (N 2) shale from 715.1 to 721.0 ft and 722.7 to 725.6 ft. Predominantly dark olive-gray (5 Y 4/1) shale from 708.6 to 709.8 ft and 712.0 to 714.2 ft. Intensely fractured and slickensided throughout. Dip 20° at 714 ft.

726.5 to 749.5 Shale, grayish-black (N 2). Fractured and slickensided.

749.5 to 750.3 Shale, dark olive-gray (5 Y 3/1 interbedded with olive-black (5 Y 2/1) shale; intensely fractured. Dip 30°.

750.3 to 750.9 Shale, grayish-black (N 2), intensely fractured.

750.9 to 751.5 Shale, olive-gray (5 Y 4/1), slickensided on most surfaces.

751.5 to 752.9 Shale, grayish-black (N 2) with rip-up clasts of dark olive-gray (5 Y 3/1) shale.

752.9 to 753.6 Shale, dark olive-gray (5 Y 3/1).

753.6 to 757.2 Shale, grayish-black (N 2).

757.2 to 758.1 Shale, dark olive-gray (5 Y 3/1).

758.1 to 758.7 Shale, grayish-black (N 2).

758.7 to 760.1 Shale, dark olive-gray (5 Y 3/1).

760.1 to 767.0 Shale, grayish-black (N 2). Intensely fractured and slickensided in lower third of unit.

767.0 to 789.3 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided. Dip 28° at 767 ft.

789.3 to 795.7 Shale, grayish-black (N 2), interbedded with 40 percent olive-gray (5 Y 4/1) shale. Dip 20° at 791.6 ft.

795.7 to 796.9 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided.

796.9 to 797.4 Shale, grayish-black (N 2), interbedded with 40 percent olive-gray (5 Y 4/1).

797.4 to 801.5 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided.

801.5 to 803.1 Shale, grayish-black (N 2), interbedded with 40 percent olive-gray (5 Y 4/1) shale.

803.1 to 804.6 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided.

804.6 to 806.1 Shale, silty, dusky yellowish-brown (10 YR 3/1).
Fractured and slickensided.

806.1 to 813.0 Shale, grayish-black (N 2), interbedded with 40 percent olive-gray (5 Y 4/1) shale.

813.0 to 814.0 Shale, grayish-black (N 2).

814.0 to 822.8 Shale, grayish-black (N 2), interbedded with 40 percent olive-gray (5 Y 4/1) shale. Predominantly grayish-black shale from 815.5 to 815.9 ft. Dip 23°.

822.8 to 824.9 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided.

824.9 to 825.4 Shale, grayish-black (N 2), interbedded with 40 percent olive-gray (5 Y 4/1) shale.

825.4 to 826.0 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided.

826.0 to 830.1 Shale, grayish-black (N 2), interbedded with 40 percent olive-gray (5 Y 4/1) shale.

830.1 to 833.0 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided.

833.0 to 835.5 Shale, grayish-black (N 2), interbedded with 40 percent olive-gray (5 Y 4/1) shale.

835.5 to 837.0 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided.

837.0 to 839.5 Shale, grayish-black (N 2), interbedded with 40 percent olive-gray (5 Y 4/1) shale.

839.5 to 846.5 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided.

846.5 to 851.4 Shale, grayish-black (N 2), interbedded with olive-gray (5 Y 4/1) shale from 849.0 to 849.4, 849.5 to 849.8, and 850.3 to 851.0 ft. Fractured and slickensided.

851.4 to 852.4 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Fractured and slickensided.

852.4 to 852.8 Shale, grayish-black (N 2). Intensely fractured and slickensided.

852.8 to 853.6 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Fractured and slickensided.

853.6 to 855.5 Shale, grayish-black (N 2), fractured and slickensided.

855.5 to 866.4 Shale, olive-gray (5 Y 4/1), fractured and slickensided. Mottled olive-black (5 Y 2/1) and olive-gray (5 Y 4/1) shale from 858.5 to 859.8, 862.5 to 863.1, and 864.2 to 865.7 ft.

866.4 to 869.6 Shale, grayish-black (N 2). Intensely fractured and slickensided.

869.6 to 870.6 Shale, olive-gray (5 Y 4/1), slickensided.

870.6 to 898.5 Shale, grayish-black (N 2), interbedded with 10 percent greenish-gray (5 GY 6/1) shale. Greenish-gray (5 GY 6/1) shale from 872.9 to 873.0, 874.0 to 874.2, 877.9 to 878.2, 879.6 to 880.0, 881.2 to 881.5, 882.5 to 882.6, and 886.5 to 887.9 ft. Slickensided.

898.5 to 902.0 Shale, olive-gray (5 Y 4/1), interbedded with 40 percent grayish-black (N 2) shale.

902.0 to 906.2 Shale, grayish-black (N 2), interbedded with 10 to 15 percent olive-gray (5 Y 4/1) shale.

906.2 to 907.0 Shale, olive-gray (5 Y 4/1), fractured and slickensided.

907.0 to 908.1 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

908.1 to 912.7 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).
Grades to 50 percent grayish-black (N 2) shale from
909.9 to 910.5 ft.

912.7 to 913.2 Shale, grayish-black (N 2), containing pyrite nodules as
much as 0.05 ft thick.

913.2 to 914.5 Shale, dark olive-gray (5 Y 3/1) to olive-gray (5 Y 4/1).
Fractured and slickensided.

914.5 to 916.0 Shale, grayish-black (N 2).

916.0 to 916.6 Shale, grayish-black (N 2), interbedded with 40 percent
olive-gray (5 Y 4/1) shale.

916.6 to 919.5 Shale, olive-gray (5 Y 4/1), becomes interbedded with
30 percent grayish-black (N 2) shale in the basal part
of the unit. Intensely fractured and slickensided.

919.5 to 923.4 Shale, grayish-black (N 2). Slickensided.

923.4 to 924.6 Shale, grayish-black (N 2), interbedded with 50 percent
olive-gray (5 Y 4/1) shale.

924.6 to 925.5 Shale, grayish-black (N 2). Intensely fractured and
slickensided.

925.5 to 927.7 Shale, olive-gray (5 Y 4/1). Fractured and slickensided.

927.7 to 928.8 Shale, grayish-black (N 2) containing a few beds of
olive-gray (5 Y 4/1) shale. Fractured and slickensided.

928.8 to 930.0 Shale, olive-gray (5 Y 4/1), interbedded with 10 percent
grayish-black (N 2) shale.

930.0 to 933.8 Shale, grayish-black (N 2), interbedded with 15 percent olive-gray (5 Y 4/1) shale, laminated. Fractured.

933.8 to 937.0 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

937.0 to 937.5 Shale, olive-gray (5 Y 4/1). Intensely fractured and slickensided.

937.5 to 951.0 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1). Fractured and slickensided.

951.0 to 1005.0 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1), interbedded with 20 percent grayish-black (N 2) to olive-black (5 Y 2/1) shale, thin- to thick-bedded. Fractured throughout, intensely fractured from 991.9 to 1005.5 ft. Dip 35° at 969 ft.

1005.5 to 1017.5 Shale, grayish-black (N 2), thin-bedded to very thick bedded interbedded with 20 percent olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1) shale, thin-bedded. Slickensided.

1017.5 to 1030.7 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1), interbedded with 30 percent grayish-black (N 2) shale, thin- to medium-bedded. Intensely fractured and slickensided.

1030.7 to 1040.0 Shale, grayish-black (N 2), interbedded with 50 percent olive-gray (5 Y 4/1), very thin bedded.

1040.0 to 1043.3 Shale, grayish-black (N 2), interbedded with 5 percent dark olive-gray (5 Y 3/1) shale. Conodonts.

1043.3 to 1045.8 Shale, olive-gray (5 Y 4/1), interbedded with 40 percent grayish-black (N 2) shale, very thin bedded.

1045.8 to 1047.6 Shale, grayish-black (N 2).

1047.6 to 1050.1 Shale, grayish-black (N 2), interbedded with 50 percent olive-gray (5 Y 4/1) shale.

1050.1 to 1051.4 Shale, olive-gray (5 Y 4/1).

1051.4 to 1051.8 Shale, olive-black (5 Y 2/1) and olive-gray (5 Y 4/1). Intensely fractured and slickensided.

1051.8 to 1052.3 Shale, silty, olive-black (5 Y 2/1) and olive-gray (5 Y 4/1).

1052.3 to 1053.0 Shale, grayish-black (N 2), interbedded with 50 percent olive-gray (5 Y 4/1) shale. Slickensided on most surfaces.

1053.0 to 1054.2 Shale, olive-gray (5 Y 4/1). Slickensided.

1054.2 to 1062.0 Shale, grayish-black (N 2), interbedded with 10 percent olive-gray (5 Y 4/1) shale. Fractured and slickensided.

1062.0 to 1063.9 Shale, olive-gray (5 Y 4/1), grading to dark olive-gray (5 Y 3/1) or olive-black (5 Y 2/1). Fractured and slickensided.

1063.9 to 1064.5 Shale, olive-gray (5 Y 4/1). Fractured and slickensided.

1064.5 to 1066.5 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent grayish-black (N 2) shale. Intensely fractured and slickensided.

1066.5 to 1086.3 Shale, grayish-black (N 2), thin-bedded to very thick bedded; interbedded with 10 percent olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1) thin-bedded shale.

1086.3 to 1088.8 Shale, olive-gray (5 Y 4/1). Pyrite bed 0.02 ft thick at top of section. Slickensided.

1088.8 to 1092.6 Shale, olive-gray (5 Y 4/1) and grayish-black (N 2).
Intensely fractured and slickensided.

1092.6 to 1093.5 Shale, olive-gray (5 Y 4/1). Slickensided.

1093.5 to 1097.0 Shale, grayish-black (N 2), interbedded with 20 percent
olive-gray (5 Y 4/1) shale. Dip 23°.

1097.0 to 1099.6 Shale, olive-gray (5 Y 4/1). Pyrite nodules, slickensided.

1099.6 to 1100.1 Shale, grayish-black (N 2), interbedded with 30 percent
olive-gray (5 Y 4/1) shale.

1100.1 to 1102.3 Shale, olive-gray (5 Y 4/1).

1102.3 to 1102.9 Shale, grayish-black (N 2).

1102.9 to 1141.0 Shale, olive-gray (5 Y 4/1) and dark olive-gray (5 Y 3/1)
medium- to thick-bedded, interbedded with 35 percent
grayish-black (N 2) and dark-gray (N 3) thin- to thick-bedded
shale. Siltstone bed 0.6 ft thick from 1110.3 to 1110.9 ft.
Siltstone bed 0.3 ft thick from 1127.8 to 1128.1 ft.
Slickensided. Dip 60° at 1136 ft.

1141.0 to 1143.7 Shale, grayish-black (N 2). Intensely fractured and
slickensided. Dip 50° at 1141 ft.

1143.7 to 1144.7 Shale, grayish-black (N 2), interbedded with 30 percent
olive-gray (5 Y 4/1) shale.

1144.7 to 1145.0 Shale, olive-gray (5 Y 4/1).

1145.0 to 1146.8 Shale, grayish-black (N 2). Slickensided.

1146.8 to 1152.8 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1),
Interbedded with 20 percent grayish-black (N 2) shale.
Intensely fractured and slickensided.

1152.8 to 1153.6 Shale, grayish-black (N 2). Slickensided.

1153.6 to 1155.6 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

1155.6 to 1156.3 Shale, grayish-black (N 2), interbedded with 30 percent olive-gray (5 Y 4/1) shale.

1156.3 to 1157.0 Shale, olive-gray (5 Y 4/1), grades to dark olive-gray (5 Y 3/1).

1157.0 to 1157.2 Shale, grayish-black (N 2).

1157.2 to 1157.6 Shale, very silty, light olive-gray (5 Y 5/2).

1157.6 to 1159.2 Shale, dark olive-gray (5 Y 3/1) to olive-black (5 Y 2/1), interbedded with 40 percent olive-gray (5 Y 4/1) shale.

1159.2 to 1160.0 Shale, olive-gray (5 Y 4/1), grades to dark olive-gray (5 Y 3/1).

1160.0 to 1160.7 Shale, silty, light olive-gray (5 Y 5/2).

1160.7 to 1161.1 Shale, dark olive-gray (5 Y 3/1).

1161.1 to 1161.7 Shale, olive-gray (5 Y 4/1).

1161.7 to 1162.0 Shale, grayish-black (N 2).

1162.0 to 1163.8 Shale, olive-gray (5 Y 4/1).

1163.8 to 1165.4 Shale, grayish-black (N 2).

1165.4 to 1166.0 Shale, olive-gray (5 Y 4/1).

1166.0 to 1166.5 Shale, olive-black (5 Y 2/1) to grayish-black (N 2).

1166.5 to 1167.7 Shale, olive-gray (5 Y 4/1).

1167.7 to 1168.0 Shale, grayish-black (N 2).

1168.0 to 1168.3 Shale, dark olive-gray (5 Y 3/1).

1168.3 to 1168.9 Shale, grayish-black (N 2). Dip 23°.

1168.9 to 1169.1 Shale, grayish-black (N 2) and dark olive-gray (5 Y 3/1).

1169.1 to 1169.35 Shale, grayish-black (N 2).

1169.35 to 1169.6 Shale, olive-gray (5 Y 4/1).

1169.6 to 1169.9 Shale, grayish-black (N 2), interbedded with 20 percent dark olive-gray (5 Y 3/1) shale. Pyrite nodules.

1169.9 to 1171.1 Shale, olive-gray (5 Y 4/1).

1171.1 to 1171.4 Siltstone.

1171.4 to 1172.3 Shale, olive-gray (5 Y 4/1).

1172.3 to 1173.0 Shale, grayish-black (N 2), contains rip-up clasts of olive-gray (5 Y 4/1) shale.

1173.0 to 1174.9 Shale, olive-gray (5 Y 4/1), interbedded with 30 percent olive-black (5 Y 2/1) shale. Intensely fractured.

1174.9 to 1175.2 Shale, grayish-black (N 2), contains rip-up clasts of olive-gray (5 Y 4/1) shale.

1175.2 to 1176.5 Shale, olive-gray (5 Y 4/1) to olive-black (5 Y 2/1).

1176.5 to 1177.5 Shale, grayish-black (N 2).

1177.5 to 1177.9 Shale, olive-gray (5 Y 4/1).

1177.9 to 1179.4 Shale, olive-black (5 Y 2/1), interbedded with 50 percent olive-gray (5 Y 4/1) shale.

1179.4 to 1180.3 Shale, olive-gray (5 Y 4/1).

1180.3 to 1180.5 Siltstone.

1180.5 to 1181.3 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

1181.3 to 1181.8 Shale, grayish-black (N 2), interbedded with 30 percent olive-gray (5 Y 4/1) shale.

1181.8 to 1183.7 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

1183.7 to 1184.0 Shale, grayish-black (N 2).

1184.0 to 1185.8 Shale, olive-gray (5 Y 4/1).

1185.8 to 1187.5 Shale, olive-black (5 Y 2/1) to grayish-black (N 2).

1187.5 to 1188.3 Shale, olive-gray (5 Y 4/1).

1188.3 to 1188.5 Shale, grayish-black (N 2).

1188.5 to 1189.7 Shale, olive-gray (5 Y 4/1).

1189.7 to 1190.2 Shale, grayish-black (N 2), interbedded with 30 percent olive-gray (5 Y 4/1) shale.

1190.2 to 1190.5 Shale, olive-gray (5 Y 4/1), interbedded with 10 percent grayish-black (N 2) shale.

1190.5 to 1192.2 Shale, grayish-black, interbedded with 20 percent olive-gray (5 Y 4/1) shale.

1192.2 to 1193.8 Shale, olive-gray (5 Y 4/1).

1193.8 to 1194.1 Shale, grayish-black (N 2).

1194.1 to 1194.2 Shale, grayish-black (N 2), contains olive-gray (5 Y 4/1) shale rip-up clasts.

1194.2 to 1195.6 Shale, grayish-black (N 2), contains 0.1 ft thick bed of olive-gray (5 Y 4/1) shale.

1195.6 to 1198.5 Shale, olive-gray (5 Y 4/1). Dip 46° at 1198.4 ft.

1198.5 to 1198.9 Shale, grayish-black (N 2).

1198.9 to 1200.2 Shale, olive-gray (5 Y 4/1). Slickensided.

1200.2 to 1200.3 Shale, grayish-black (N 2).

1200.3 to 1200.8 Shale, olive-gray (5 Y 4/1).

1200.8 to 1201.1 Shale, grayish-black (N 2).

1201.1 to 1202.1 Shale, olive-gray (5 Y 4/1). Dip 20°.

1202.1 to 1202.4 Shale, grayish-black (N 2). Pyrite nodules.

1202.4 to 1205.8 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1),
interbedded with 10 percent grayish-black (N 2) shale.
Intensely fractured and slickensided.

1205.8 to 1212.9 Shale, grayish-black (N 2), interbedded with 30 percent
dark olive-gray (5 Y 3/1) to olive-black (5 Y 2/1) shale.
Intensely fractured.

1212.9 to 1215.3 Shale, dark olive-gray (5 Y 3/1), interbedded with 20
percent grayish-black (N 2) shale.

1215.3 to 1218.2 Shale, grayish-black (N 2), interbedded with 20 percent
dark olive-gray (5 Y 3/1) shale. Intensely fractured
and slickensided.

1218.2 to 1219.7 Shale, olive-gray (5 Y 4/1). Dip 10°.

1219.7 to 1220.2 Shale, grayish-black (N 2), interbedded with 30 percent
olive-gray (5 Y 4/1) shale.

1220.2 to 1220.9 Shale, olive-gray (5 Y 4/1), grading to dark olive-gray
(5 Y 3/1).

1220.9 to 1221.2 Siltstone.

1221.2 to 1222.0 Shale, dark olive-gray (5 Y 3/1).

1222.0 to 1222.5 Shale, grayish-black (N 2), interbedded with 20 percent
olive-gray (5 Y 4/1) shale.

1222.5 to 1224.4 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

1224.4 to 1224.8 Shale, grayish-black (N 2).

1224.8 to 1226.3 Shale, olive-gray (5 Y 4/1). Pyrite nodules.

1226.3 to 1227.8 Shale, grayish-black (N 2), interbedded with 20 percent olive-gray (5 Y 4/1) shale. Dip 10°.

1227.8 to 1228.4 Shale, olive-gray (5 Y 4/1).

1228.4 to 1228.7 Shale, grayish-black (N 2).

1228.7 to 1230.3 Shale, olive-gray (5 Y 4/1).

1230.3 to 1230.7 Shale, grayish-black (N 2), interbedded with 20 percent olive-gray (5 Y 4/1) shale.

1230.7 to 1230.9 Shale, olive-gray (5 Y 4/1).

1230.9 to 1232.1 Shale, olive-black (5 Y 2/1), interbedded with 20 percent olive-gray (5 Y 4/1) shale. Pyrite nodules and calcite-filled fractures.

1232.1 to 1239.3 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1). Fractured and slickensided.

1239.3 to 1243.2 Shale, grayish-black (N 2), interbedded with 30 percent olive-gray (5 Y 4/1) shale. Intensely fractured and slickensided.

1243.2 to 1243.7 Shale, olive-gray (5 Y 4/1), interbedded with 10 percent grayish-black (N 2) shale.

1243.7 to 1243.9 Shale, grayish-black (N 2). Intensely fractured.

1243.9 to 1244.7 Shale, olive-gray (5 Y 4/1). Dip 40°.

1244.7 to 1245.0 Shale, grayish-black (N 2).

1245.0 to 1245.2 Shale, dark olive-gray (5 Y 3/1).

1245.2 to 1245.5 Shale, grayish-black (N 2). Fractured.

1245.5 to 1248.3 Shale, olive-gray (5 Y 4/1) and grayish-black (N 2).
Intensely fractured and slickensided.

1248.3 to 1248.9 Shale, dark olive-gray (5 Y 3/1). Fractured and
slickensided.

1248.9 to 1249.1 Shale, grayish-black (N 2). Fractured.

1249.1 to 1250.5 Shale, olive-gray (5 Y 4/1), interbedded with 10 percent
grayish-black (N 2) shale. Intensely fractured and
slickensided.

1250.5 to 1250.8 Siltstone.

1250.8 to 1251.7 Shale, dark olive-gray (5 Y 3/1), grading to olive-gray
(5 Y 4/1). Fractured and slickensided.

1251.7 to 1252.1 Shale, grayish-black (N 2). Fractured.

1252.1 to 1252.9 Shale, olive-gray (5 Y 4/1) to dark olive-gray
(5 Y 3/1). Fractured. Dip 22°.

1252.9 to 1253.1 Siltstone.

1253.1 to 1253.9 Shale, dark olive-gray (5 Y 3/1) to olive-gray
(5 Y 4/1). Fractured.

1253.9 to 1254.5 Shale, grayish-black (N 2), interbedded with 30
percent dark olive-gray (5 Y 3/1) shale. Fractured.

1254.5 to 1256.7 Shale, olive-gray (5 Y 4/1).

1256.7 to 1257.0 Shale, grayish-black (N 2). Fractured.

1257.0 to 1258.3 Shale, olive-gray (5 Y 4/1).

1258.3 to 1258.8 Shale, grayish-black (N 2), interbedded with 20 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided.

1258.8 to 1260.6 Shale, dark olive-gray (5 Y 3/1). Intensely fractured. Dip 25°.

1260.6 to 1261.6 Shale, grayish-black (N 2), interbedded with 10 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured.

1261.6 to 1263.1 Shale, olive-gray (5 Y 4/1).

1263.1 to 1263.5 Shale, olive-black (5 Y 2/1), interbedded with 20 percent dark olive-gray (5 Y 3/1) shale.

1263.5 to 1264.5 Shale, olive-gray (5 Y 4/1), grading to dark olive-gray (5 Y 3/1). Fractured and slickensided.

1264.5 to 1264.7 Siltstone.

1264.7 to 1265.1 Shale, dark olive-gray (5 Y 3/1).

1265.1 to 1265.5 Shale, olive-gray (5 Y 4/1).

1265.5 to 1266.0 Shale, grayish-black (N 2).

1266.0 to 1266.5 Shale, olive-gray (5 Y 4/1).

1266.5 to 1266.9 Siltstone, shaly, light olive-gray (5 Y 5/2).

1266.9 to 1267.8 Shale, dark olive-gray (5 Y 3/1), grading to olive-gray (5 Y 4/1). Dip 25°.

1267.8 to 1268.2 Shale, grayish-black (N 2).

1268.2 to 1269.9 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

1269.9 to 1271.2 Shale, olive-black (5 Y 2/1), interbedded with 10 percent dark olive-gray (5 Y 3/1) shale.

1271.2 to 1271.9 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

1271.9 to 1272.2 Shale, grayish-black (N 2).

1272.2 to 1273.5 Shale, olive-gray (5 Y 4/1).

1273.5 to 1277.0 Shale, grayish-black (N 2), interbedded with 30 percent dark olive-gray (5 Y 3/1) shale. Fractured and slickensided. Dip 20°.

1277.0 to 1278.4 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

1278.4 to 1285.5 Shale, grayish-black (N 2), interbedded with 30 percent olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1) shale. Fractured. Dip 40°.

1285.5 to 1287.8 Shale, dark olive-gray (5 Y 3/1) to olive-black (5 Y 2/1), interbedded with 30 percent olive-gray (5 Y 4/1) shale.

1287.8 to 1288.7 Shale, olive-gray (5 Y 4/1).

1288.7 to 1292.2 Shale, grayish black (N 2), interbedded with 20 percent olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1) shale. Pyrite nodules.

1292.2 to 1294.7 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1). Pyrite nodules at the top of unit. Dip 35°.

1294.7 to 1295.5 Shale, grayish-black (N 2), interbedded with 20 percent dark olive-gray (5 Y 3/1) shale. Intensely fractured and slickensided.

1295.5 to 1297.2 Shale, olive-gray (5 Y 4/1), grading to dark olive-gray (5 Y 3/1).

1297.2 to 1297.8 Shale, grayish-black (N 2), interbedded with 50 percent dark olive-gray (5 Y 3/1) shale.

1297.8 to 1298.6 Shale, olive-gray (5 Y 4/1).

1298.6 to 1298.9 Shale, grayish-black (N 2).

1298.9 to 1299.0 Shale, olive-gray (5 Y 4/1).

1299.0 to 1300.0 Shale, olive-gray (5 Y 4/1) and grayish-black (N 2).

1300.0 to 1301.6 Shale, dark olive-gray (5 Y 3/1), grading to olive-gray (5 Y 4/1). Fractured.

1301.6 to 1302.4 Shale, grayish-black (N 2), interbedded with 20 percent olive-gray (5 Y 4/1) shale.

1302.4 to 1304.3 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

1304.4 to 1304.7 Siltstone.

1304.7 to 1306.4 Shale, olive-gray (5 Y 4/1), contains a 0.2 ft thick bed of very silty shale.

1306.4 to 1309.4 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1). Dip 30°.

1309.4 to 1309.8 Shale, grayish-black (N 2).

1309.8 to 1311.5 Shale, olive-gray (5 Y 4/1), contains rip-up clasts of grayish-black (N 2) shale. Fractured.

1311.5 to 1312.8 Shale, grayish-black (N 2), interbedded with 10 percent dark olive-gray (5 Y 3/1) shale.

1312.8 to 1314.31 Shale, olive-gray (5 Y 4/1). Pyrite nodules at top of section.

1314.3 to 1314.7 Shale, grayish-black (N 2), interbedded with 20 percent olive-gray (5 Y 4/1) shale.

1314.7 to 1315.4 Shale, olive-gray (5 Y 4/1) grading to dark olive-gray (5 Y 3/1).

1315.4 to 1315.7 Siltstone.

1315.7 to 1433.3 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1), thin-bedded to very thick-bedded; interbedded with 30 percent grayish-black (N 2), thin- to thick-bedded shale. Beds of limestone from 1357.3 to 1357.6, 1358.9 to 1359.2, 1388.5 to 1388.9, and 1404.2 to 1404.4 ft. Intensely fractured from 1344.2 to 1349.6, 1350.0 to 1353.3, 1356.4 to 1357.3, and 1359.2 to 1360.5 ft. Pyrite nodules associated with several grayish-black (N 2) shale beds. Dip 30° at 1316 and 1341 ft; 50° at 1353 ft; 42° at 1360 ft; 32° at 1362 ft; 27° at 1372 ft; 25° at 1379 ft; 20° at 1389 ft; 15° at 1397 ft; and 18° at 1417 ft.

1433.3 to 1434.6 Limestone.

1434.6 to 1435.0 Shale, olive-black (5 Y 2/1), grades to grayish-black (N 2).

1435.0 to 1435.6 Shale, dark olive-gray (5 Y 3/1). Pyrite nodules at top.

1435.6 to 1443.0 Shale, olive-black (5 Y 2/1), interbedded with 20 percent dark olive-gray (5 Y 3/1) shale in the basal part. Dip 26°.

1443.0 to 1443.4 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1).

1443.4 to 1443.9 Shale, olive-black (5 Y 2/1) to grayish-black (N 2).

1443.9 to 1444.0 Shale, olive-gray (5 Y 4/1).

1444.0 to 1449.2 Shale, grayish-black (N 2) to olive-black (5 Y 2/1), interbedded with 20 percent olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1) shale.

1449.2 to 1452.9 Shale, grayish-black (N 2). Pyrite bed 0.03 ft thick at 1451.0 ft and 0.1 ft thick at 1452.0 ft. Limestone bed 0.01 ft thick at base of section.

1452.9 to 1453.4 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1). Becomes very silty at base of section.

1453.4 to 1454.5 Shale, grayish-black (N 2).

1454.5 to 1454.9 Limestone.

1454.9 to 1457.1 Shale, dark olive-gray (5 Y 3/1) grades to olive-black (5 Y 2/1). Limestone bed 0.1 ft thick at base of unit.

1457.1 to 1461.5 Shale, grayish-black (N 2) to olive-black (5 Y 2/1), interbedded with 30 percent olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1) shale. Dip 20°.

1461.5 to 1462.2 Shale, grayish-black (N 2). Calcite-filled fractures.

1462.2 to 1463.0 Shale, grayish-black (N 2), interbedded with 20 percent olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1) shale.

1463.0 to 1466.0 Shale, grayish-black (N 2), interbedded with 10 percent olive-gray (5 Y 4/1) shale.

1466.0 to 1466.3 Shale, olive-gray (5 Y 4/1).

1466.3 to 1466.7 Shale, grayish-black (N 2).

1466.7 to 1467.9 Shale, grayish-black (N 2), interbedded with 50 percent dark olive-gray (5 Y 3/1) shale.

1467.9 to 1468.7 Shale, olive-black (5 Y 2/1) to grayish-black (N 2).

1468.7 to 1473.8 Shale, olive-gray (5 Y 4/1) to dark olive-gray (5 Y 3/1), interbedded with 10 percent grayish-black (N 2) shale. Contains four limestone beds each as much as 0.02 ft thick.

1473.8 to 1483.5 Shale, grayish-black (N 2), interbedded with 10 percent olive-gray (5 Y 4/1) and olive-black (5 Y 2/1) shale. Pyrite nodules. Dip 20°.

1483.5 to 1484.0 Shale, grayish-black (N 2) and dark olive-gray (5 Y 3/1).

1484.0 to 1485.0 Shale, grayish-black (N 2), containing limestone rip-up clasts. Basal 0.2 ft is limestone.

1485.0 to 1485.4 Shale, dark olive-gray (5 Y 3/1), interbedded with 20 percent olive-black (5 Y 2/1) shale.

1485.4 to 1485.8 Limestone grading to 50 percent intercalated limestone and grayish-black (N 2) shale. Rip-up clasts. Dip 40°.

1485.8 to 1486.7 Shale, grayish-black (N 2) to black (N 1). Calcite-filled fractures, slickensided.

1486.7 to 1487.6 Shale, dark olive-gray (5 Y 3/1), interbedded with 30 percent olive-black (5 Y 2/1) shale.

1487.6 to 1491.7 Shale, grayish-black (N 2). Calcite-filled fractures, slickensided.

1491.7 to 1492.4 Shale, calcareous.

1492.4 to 1499.0 Shale, black (N 1) to grayish-black (N 2), grades to all black. Calcite-filled fractures, slickensided.

Wildcat Valley Sandstone(?)

- 1499.0 to 1507.0 Limestone, medium light-gray (N 6), finely crystalline contains irregular laminae of medium-gray calcareous shale, pyritic. Contains corals.
- 1507.0 to 1512.0 Sandstone, slightly calcareous, fine- to coarse-grained, medium-gray (N 5), containing clasts of shale, siltstone, and sandstone at base.
- 1512.0 to 1513.9 Shale, calcareous, greenish-gray (5 GY 6/1) to medium-gray (N 5), containing laminae of very fine grained light-gray (N 7) sandstone. Fossiliferous.
- 1513.9 to 1525.1 Sandstone, calcareous, medium-gray (N 5), containing few scattered quartz pebbles. Conglomeratic near base.

LITHOLOGIC DESCRIPTION

TDG-DOE CORED DRILL HOLE NO. 5

Grainger Formation

<u>Depth (ft)</u>	
0.0 to 20.6	Casing, no core recovered.
20.6 to 66.3	Shale, olive-gray (5 Y 4/1), and interbedded brownish-gray (5 YR 4/1) siltstone; severely deformed, folded, and faulted.
66.3 to 66.5	Shale, medium dark-gray (N 4).
66.5 to 66.7	Siltstone, olive-gray (5 Y 4/1) to brownish-gray (5 YR 4/1).
66.7 to 68.4	Shale, medium dark-gray (N 4), containing a few laminae of very fine grained, light-gray (N 7) sandstone and some brownish-gray siderite.
68.4 to 69.5	Sandstone, very fine grained, medium light-gray (N 6), containing laminae of brownish gray (5 YR 4/1) siltstone; thick-bedded at base, becomes laminated toward top.
69.5 to 69.85	Shale, medium-dark-gray (N 4).
69.85 to 69.95	Siderite, brownish-gray (5 YR 4/1).
69.95 to 70.3	Sandstone, very fine grained, light gray (N 7), laminated to ripple-bedded at top.

Chattanooga Shale

<u>Depth (ft)</u>	
70.3 to 77.2	Shale, medium gray (N 5) to medium dark-gray (N 3), containing a few laminae and burrow fillings of very fine grained, light-gray (N 7) sandstone and siltstone; folded from 73.8 to 75.4 ft.
77.2 to 79.1	Shale, silty, medium-gray (N 5) to medium dark-gray (N 3), containing a few laminae and burrow fillings of very fine grained, light-gray (N 7) sandstone.
79.1 to 79.2	Siltstone, medium light-gray (N 6) to brownish-gray (5 YR 4/1), laminated to ripple-bedded.
79.2 to 81.5	Shale, medium dark-gray (N 4), containing a few laminae of medium light-gray (N 6) siltstone.
81.5 to 82.3	Shale, medium dark-gray (N 4), containing laminae of medium light-gray (N 6) siltstone.
82.3 to 82.4	Siderite, brownish-gray (5 YR 4/1).
82.4 to 83.2	Shale, medium dark-gray (N 4), containing laminae of medium-light-gray (N 6) siltstone.
83.2 to 83.35	Siltstone, medium light-gray (N 6) to medium-gray (N 5) laminated.
83.35 to 83.45	Shale, medium dark-gray (N 4).
83.45 to 83.6	Siderite, brownish-gray (5 YR 4/1).
83.6 to 84.55	Shale, medium dark-gray (N 4), containing numerous laminae of medium light-gray (N 6) siltstone.
84.55 to 84.65	Siderite, brownish-gray (5 YR 4/1).
84.65 to 85.85	Shale, medium dark-gray (N 4), containing a few laminae of medium light-gray (N 6) siltstone.

<u>Depth (ft)</u>	
85.85 to 85.95	Siderite, brownish-gray (5 YR 4/1).
85.95 to 95.4	Shale, medium-gray (N 5) to medium dark-gray (N 4), containing a few bands of siderite as much as 0.1 ft thick, laminae and burrow fillings of medium light-gray (N 6) siltstone.
95.4 to 223.5	Shale, dark-gray (N 3), containing a few laminae of medium-gray (N 5) siltstone. Contains a few pyritized sandy burrow fillings and ripples. Beds of medium gray (N 5) siltstone from 118.6 to 118.7, 128.5 to 128.6, 133.15 to 133.2, 134.05 to 134.1, 134.3 to 134.4, 137.5 to 137.6, 138.7 to 138.8, and 140.3 to 140.4 ft. Scattered calcite-filled veins in lower part.
223.5 to 224.5	Sampled. No description available.
224.5 to 225.4	Siltstone, medium-gray (N 5), slightly pyritic.
225.4 to 226.4	Siltstone, medium-gray (N 5) to yellowish-brown (10 YR 5/2), ferruginous. Contains few quartz pebbles.
226.4 to 275.6	Siltstone, medium-gray (N 5), containing irregular slumped medium dark-gray (N 4) shale beds. Contains few veinlets of siderite.

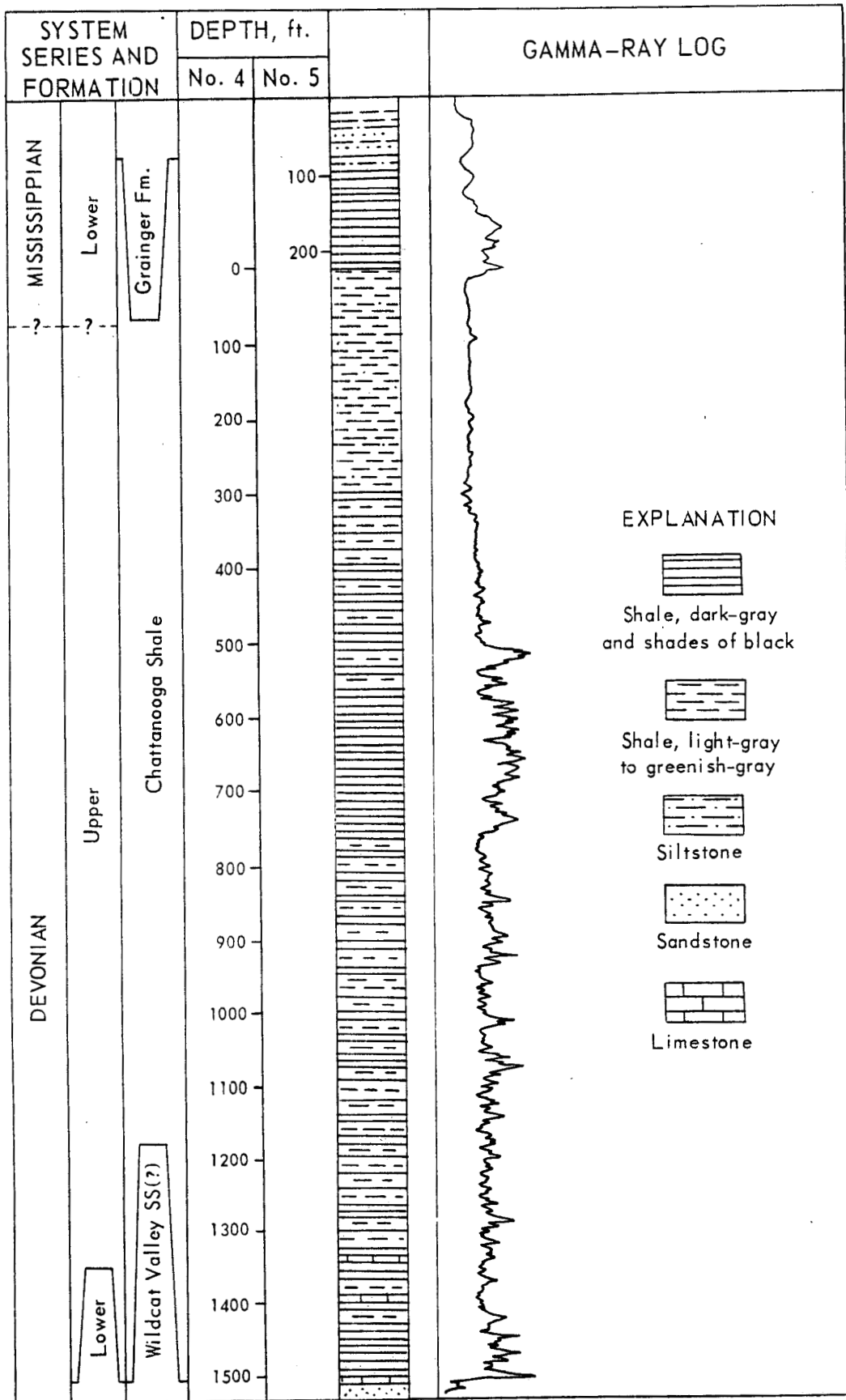


Figure 3.-- Compositd lithologic and gamma-ray logs for TDG-DOE No. 4 and No. 5 cored drill holes.

DISCUSSION

In the western part of Hawkins County, the Chattanooga Shale is stratigraphically above the Wildcat Valley Sandstone(?) of Early Devonian age and below the siltstone and shale of the Grainger Formation of Early Mississippian age.

Megascopic examination of the core material indicates that the Chattanooga is composed of about 41 percent black, brownish-black, olive-black, or grayish-black shale, 30 percent gray to olive-gray siltstone and shaley siltstone, and about 28 percent light-gray to greenish- or olive-gray shales. The various shades of darker gray to black shale are composed chiefly of clay, finely divided carbonaceous material, and quartz. Clay-size quartz grains are generally disseminated throughout the unit. Silt-size to very fine grained quartz forms very thin lighter colored beds or laminae scattered throughout the section. Noticeably, concentrations are found associated with the less radioactive gray shales in the upper one-third of the sequence. The Chattanooga Shale is mostly laminated to very thinly bedded, but some thick to massive beds are present.

Trace amounts of pyrite are common throughout the core. Concentrations of pyrite are generally found in the siltstone beds. Pyrite forms irregular nodules, veinlets, lenses, and framboidal clusters. Calcite is found in small amounts filling faults and fractures.

Several thin beds of yellowish-brown limestone were found from 1433 to 1485 ft. The beds range from 0.1 to 1.3 ft in thickness. The yellowish color suggests that these beds may be in part sideritic or dolomitic.

Fossils found in the Chattanooga Shale include the algae Tasmanites and Foerstia, a few conodonts, and trace fossils. Although Tasmanites probably occurs throughout the shale, it was only recorded in the upper half of the sequence. Foerstia was found in the TDG-DOE no. 4 core at depth of 325.4 ft. Conodonts were found in the TDG-DOE no. 4 core at 375 ft, from 600 to 660 ft, at 1434, 1043, and 1397 ft, and from 1474 to 1498 ft. The trace fossils found were burrows filled by siltstone.

Both sedimentary and tectonic structural features were seen in the core. Zones of rip-up and flow casts are found sporadically throughout the Chattanooga core. Fractures, folds, and slickensided surfaces are abundant throughout the cored sequence. No particular zone appears more intensely deformed than another. Dips recorded are relative to the normal of the core axis and range from 10° to 60°.

References

1. Goddard, E. N., and others, 1948, Rock-color chart; Washington, D.C., National Research Council, 6 p. (republished by Geological Society of America, 1951).
2. Roen, J. B., Milici, R. C., Kepferle, R. C., and Wallace, L. C., 1980a, The Chattanooga Shale (Devonian and Mississippian) from the Tennessee Division of Geology - U.S. Department of Energy cored drill holes number 1 and 2, Claiborne County, Tennessee: U.S. Department of Energy, Morgantown Energy Technology Center, Comprehensive Report METC/CR-80-1.
3. Roen, J. B., Milici, R. C., and Wallace, L. C., 1980b, The Chattanooga Shale (Devonian and Mississippian) from the Tennessee Division of Geology - U.S. Department of Energy cored drill hole number 3, Hancock County, Tennessee: U.S. Department of Energy, Morgantown Energy Technology Center, Comprehensive Report DOE/METC/10866-10.
4. Swingle, G. D., Hardeman, W. D., Fullerton, D. S., Sykes, C. R., and Miller, R. A., 1966, Geologic map of Tennessee, East Sheet: Tennessee Division of Geology, Nashville, Tennessee.