The Middle Run Formation: A Subsurface Stratigraphic Unit in Southwestern Ohio[1]

DOUGLAS L. SHRAKE, Division of Geological Survey, Ohio Department of Natural Resources, 4383 Fountain Square Drive, Columbus, OH 43224

ABSTRACT. **The Middle Run Formation, a recently described and named sedimentary unit, was encountered below the Mount Simon Sandstone (Upper Cambrian) in the Ohio Department of Natural Resources (ODNR), Division of Geological Survey (DGS) core hole DGS 2627 in Warren County, OH, (39°33'57"N latitude, 84°06'51" W longtitude). The formation is primarily a fine- to medium-grained, subangular- to subrounded-grained, siliceously and hematitically cemented, tightly compacted, grayish-red (5 R 4/2), lithic arenite. It also contains rare intervals of calcite-cemented granule- to pebble-sized lithic-fragment conglomerates, and has an average porosity of less than 2%. Sedimentary features in the formation include horizontal and ripple laminations and crossbedding. A total of 582 m of this formation's estimated 1100-m thickness were cored. The Survey core DGS 2627, reposited in the Survey's core library, is designated as the type section for the Middle Run Formation. A suite of geophysical-logs for the core hole is on file at the Survey.**

A 12.8-km seismic reflection survey across the core site shows the Middle Run Formation to be part of a sedimentary sequence within a basin having a depth of at least 5200 m. Well cuttings from other bore holes in the Cincinnati, OH, area and regional geophysical data suggest that the basin containing the Middle Run may extend north-south for 160 km and east-west for 48 km. Given its stratigraphic position, its similarity to sediments in the Midcontinent Rift System, and its possible relationship to the Grenville Orogeny, the Middle Run Formation is thought to be Late Precambrian (Keweenawan) in age.

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INTRODUCTION

The name Middle Run Formation was given to a previously unrecognized and unnamed sedimentary unit encountered below the Mount Simon Sandstone (Upper Cambrian) in southwestern Ohio (Shrake et al. 1990). The formation was discovered during the drilling of a stratigraphic reference core in southwestern Ohio by the ODNR, Division of Geological Survey (hereinafter: Survey). The purpose of the drill hole was to obtain a continuous core and geophysical-log suite from the surface into the Precambrian basement complex to serve as a reference section in the statewide stratigraphic network being developed by the Survey, and to support bedrock geologic mapping in the Warren County, OH, region.

The DGS 2627 core site is in an American Aggregates Corporation limestone quarry located 0.8 km northeast of the town of Lytle in northwestern Wayne Township, Warren County, OH (Fig. 1). The geographic coordinates for the site are 39°33'57"N latitude and 84°06'51"W longitude.

Prior to coring, a stratigraphic section of the rocks expected to be encountered at the core site was developed using available well records, core and geophysical logs, structure contour maps, and geologic reports (Shrake 1989). On the basis of these data, the top of a typical Precambrian basement complex was expected to be encountered approximately 1,100 m below the surface (surface elevation is approximately 306 m above sea level). At 1,058 m below the surface, the drill penetrated an apparent basal conglomeratic layer (Fig. 2). However, instead of encountering the anticipated crystalline or metasedimentary rocks below this layer, the drill penetrated

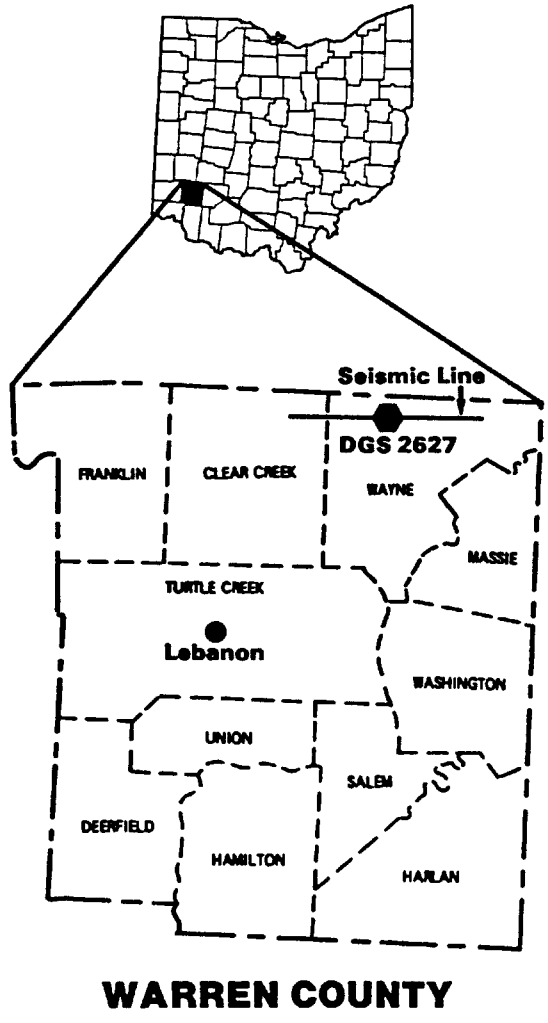

FIGURE 1. Location of corehole DGS 2627 and seismic line, ODNR-1-88. County map at a scale of approximately 1 cm = 14 km.

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another sedimentary unit (Fig. 2). This unit initially was thought to be a previously unrecognized facies of the Mount Simon Sandstone (Shrake and Hansen 1989). However, after a few hundred meters of the unit had been cored, with little change in lithology, it was concluded that a new sedimentary stratigraphic unit had been discovered. This interpretation was substantiated by a seismic reflection profile (ODNR-1-88) which revealed a basin structure, possibly rift related, underlying the Paleozoic sedimentary rocks (Wickstrom and Shrake 1989; Wolfe et al. 1989; Shrake et al. 1990, 1991) (Fig. 3).

The name for this new unit, the Middle Run Formation, was taken from a stream originating near the core site. The stream is on the U.S. Geological Survey Waynesville, OH, 7.5-minute quadrangle. Survey core DGS 2627 serves as the type section for the Middle Run Formation and is reposited at the Survey's core library in Columbus, OH (Shrake et al. 1990).

MATERIALS AND METHODS

Equipment

Core DGS 2627 was drilled using the Survey's Longyear Hydro-44 rotary coring rig operated by Michael J. Mitchell, Driller, and Mark E. Clary, Drilling Assistant. The upper 823 m of the hole were cored using NCQ drill bits, which produced a 7.5-cm-diameter core hole. The lower 817 m were cored using BCQ drill bits, which produced a 5-cm-diameter core hole.

Site Selection and Duration

The American Aggregates Corporation quarry site was selected based on its ability to provide a useful reference point for the Survey's bedrock geologic mapping program under way in the area and because it contained a water supply that would be accessible throughout the year. The core hole was started on 13 October 1987, and completed on 3 May 1989.

Geophysical Logs

BPB Instruments, Inc. was contracted to geophysically log the hole. Geophysical logs available for DGS 2627 include: gamma ray, neutron-porosity, bulk density, three-arm caliper, resistivity, temperature, verticality, and sonic. To prevent the Knox Dolomite from caving in while the lower portion of the hole was logged, the NCQ drill rod was left in the hole as casing. The temperature log was not run in the upper 823 m of the hole because of the NCQ drill rod remaining in the core hole. The sonic log was not run in the lower 817 m of the hole because the diameter of the sonic geophysical sonde was larger than that of the core hole. The geophysical logs are on file at the Survey office in Columbus.

Seismic Reflection Profile

The 12.8-km seismic reflection profile, designated ODNR-1-88, was financed by private sources and managed by Drs. Paul J. Wolfe and Benjamin H. Richard of the Departments of Geological Sciences and Physics, Wright State University (Dayton, OH), and Gary W. Sitler of Stocker and Sitler, Inc. (Newark, OH). The line was shot by Paragon Geophysical, Inc., and processed independently by four companies (see Acknowledgements).

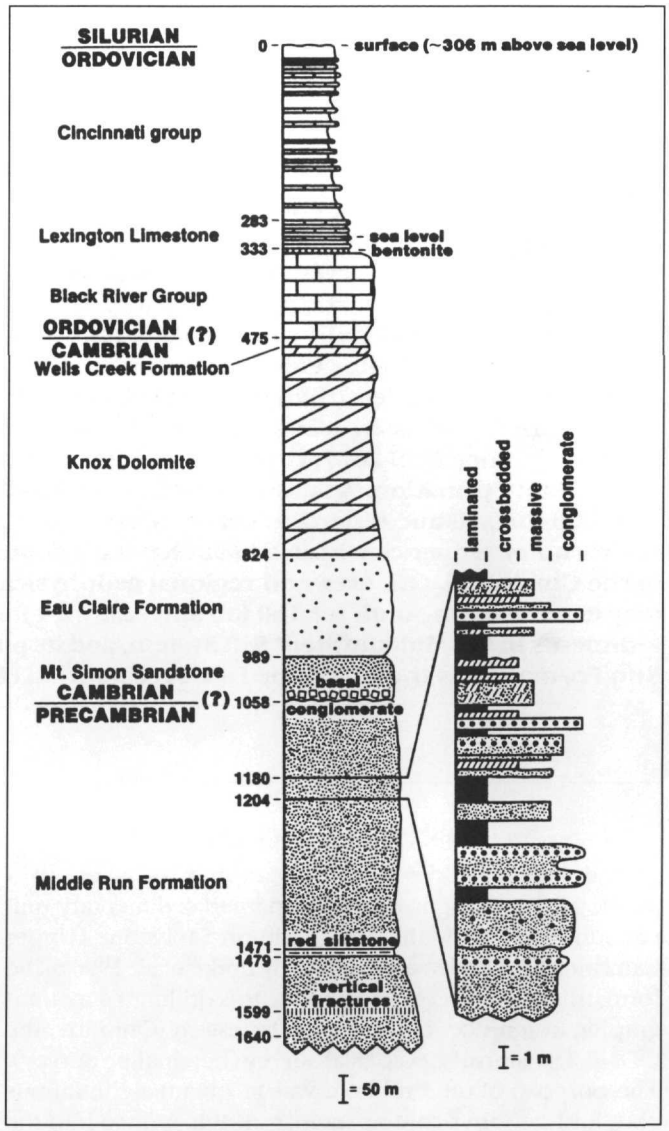

FIGURE 2. Schematic stratigraphic section of DGS 2627 and a detailed section of an interval showing depositional variations present in the Middle Run Formation (from Shrake et al. 1991).

Core Description

The core was described megascopically on its outer surface and, in selected sawed-core segments, with the aid of a 10x magnifying lens and 10-30x binocular microscope. (For a detailed description of the Middle Run Formation, see Appendix.) To supplement the hand description, 13 thin sections were made of the Middle Run Formation. The thin sections were stained for estimating percentage of potash feldspar and calcium-rich plagioclase. Petrographic analyses of these thin sections were conducted by Dr. Richard W. Carlton of the Survey, and Dr. Paul Edwin Potter of the University of Cincinnati, Cincinnati, OH.

RESULTS AND DISCUSSION

History of the pre-Mount Simon Interval

The pre-Mount Simon stratigraphic interval has rarely been encountered in southwestern Ohio. There have only

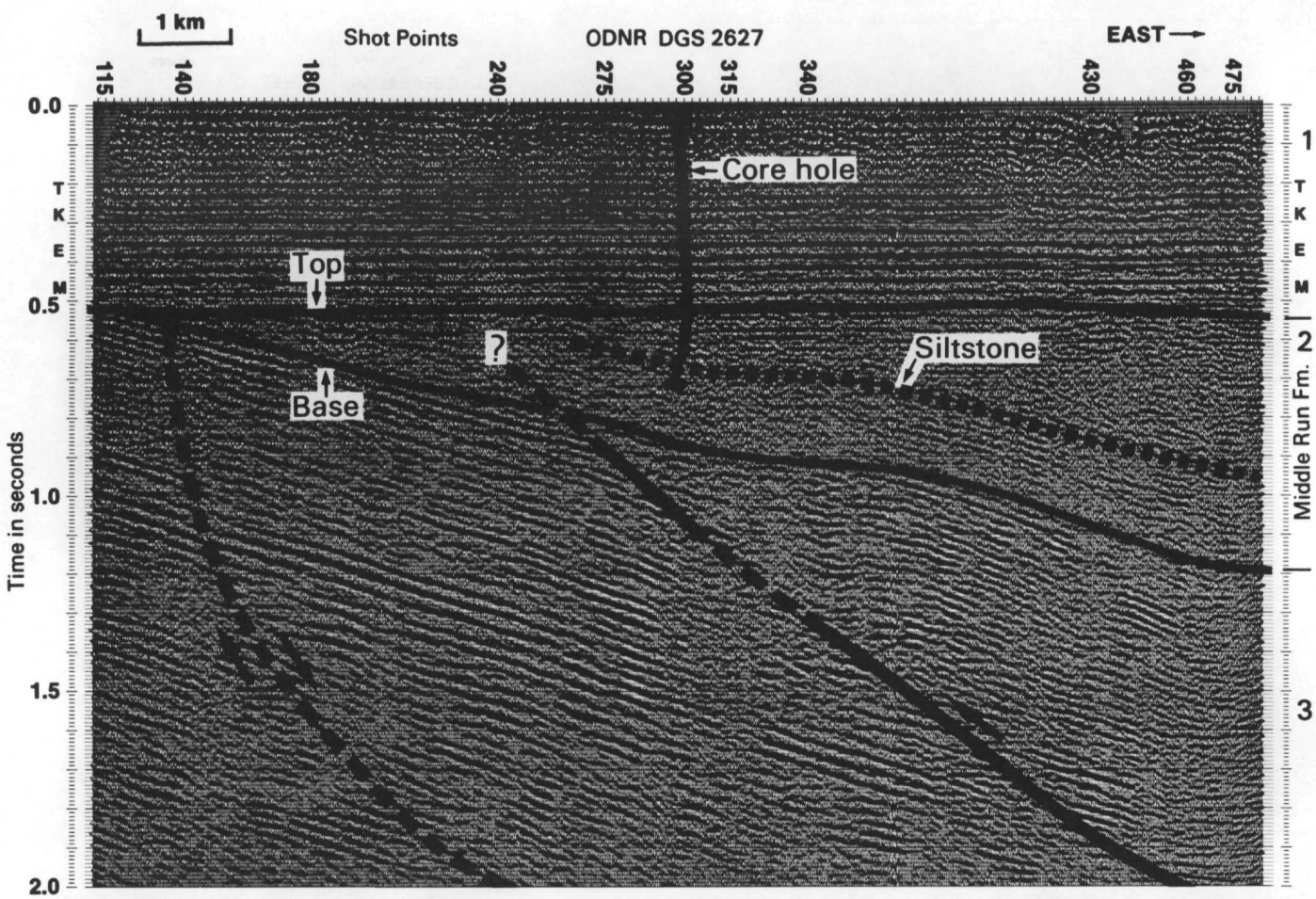

FIGURE 3. Seismic line ODNR-1-88 showing postulated structural interpretation. Faults shown by solid (possible) and dashed (projected) lines. Dotted line pattern marks approximate position of the siltstone encountered in core. Line labeled "Top" is approximate position of top of Middle Run Formation. Line labeled "Base" is assumed base of Middle Run Formation. T = top of Trenton Limestone; K = top of Knox Dolomite; E = top of Eau Claire Formation; and, M = base of Mount Simon Sandstone. 1 = horizontally bedded Paleozoic rocks; 2 = Middle Run Formation; 3 = uncored interval (modified from Shrake et al. 1991).

been about 30 bore holes reported in the region, 13 of which have penetrated the pre-Mount Simon interval (McCormick 1961, Summerson 1962, Owens 1967, Janssens 1973, Yates 1989). Prior to the drilling of DGS 2627, the pre-Mount Simon stratigraphic interval was thought to be composed of metasedimentary rocks, arkose, granite, or rhyolite (McCormick 1961, Summerson 1962, Owens 1967). A sample of the Middle Run Formation from DGS 2627 was crushed to produce cuttings for comparison with cuttings from bore holes which reached this interval in Ohio, Indiana, and Kentucky. The comparison indicates that some of these bore holes encountered the Middle Run or an equivalent sedimentary unit (Fig. 4) (Shrake et al. 1991). The misidentification of the Middle Run Formation based only on cuttings is understandable given its granitic mineralogical composition and the tightness of its compaction (Appendix) (Shrake et al. 1990).

Regional Extent and Structure

On the basis of the aeromagnetic and Bouguer gravity maps of Ohio (Hilderbrand and Kucks 1984a,b), analysis of cuttings from other bore holes in the Cincinnati, OH, area, and the 12.8-km seismic profile shot in the vicinity of the DGS 2627 core site (Shrake et al. 1990, 1991), the Middle Run Formation is believed to be in a basin having an east-west width of approximately 48 km and a minimum north-south length of approximately 160 km (Fig. 4). The Middle Run may be a rift-related sedimentary sequence. This interpretation is based on the structure shown on the seismic profile (Fig. 3) and the lithologic similarities of the formation to known rift-related sedimentary rock sequences along the Midcontinent Rift System in the Lake Superior region.

Similar Sedimentary Sequences

The Middle Run Formation appears remarkably similar to other midwestern rift-related sedimentary sequences. Probably the most similar is the Jacobsville Sandstone (Kalliokoski 1982, 1988b) of northern Michigan. In the past, the term "Jacobsville Sandstone" was used tentatively by Fettke (1948) for a red clastic layer encountered in a Putnam County, OH, well located 160 km north of the DGS 2627 site. However, Fettke thought this layer was Late Cambrian in age, not Precambrian. Another red clastic unit similar in lithology to the Jacobsville and Middle Run was reported in a well in Clark County, OH, approximately 48 km northeast of the DGS 2627 site (Wasson 1932). Lockett (1947) postulated that the sandstone in the Clark County well thickens to the south and west, filling a low in the Precambrian basement. The Copper Harbor Conglomerate or the Freda Sandstone of the Oronto Group of

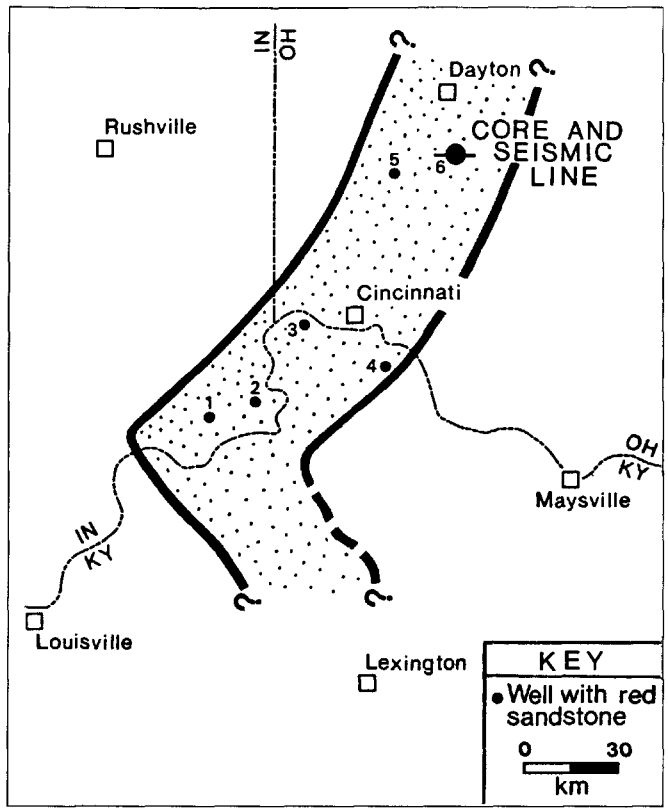

FIGURE 4. Regional map showing probable extent of the basin and other wells in the basin containing lithologic equivalents to the Middle Run Formation. Well names are: 1) Permit 46339 Switzerland County, IN; 2) Permit 29579 Switzerland County, IN; 3) Record 2343 Boone County, KY; 4) Permit 18–051 Campbell County, KY; 5) Permit 4, Lemon Twp., Butler County, OH; and, 6) DGS 2627, Wayne Twp., Warren County, OH (modified from Shrake et al. 1991).

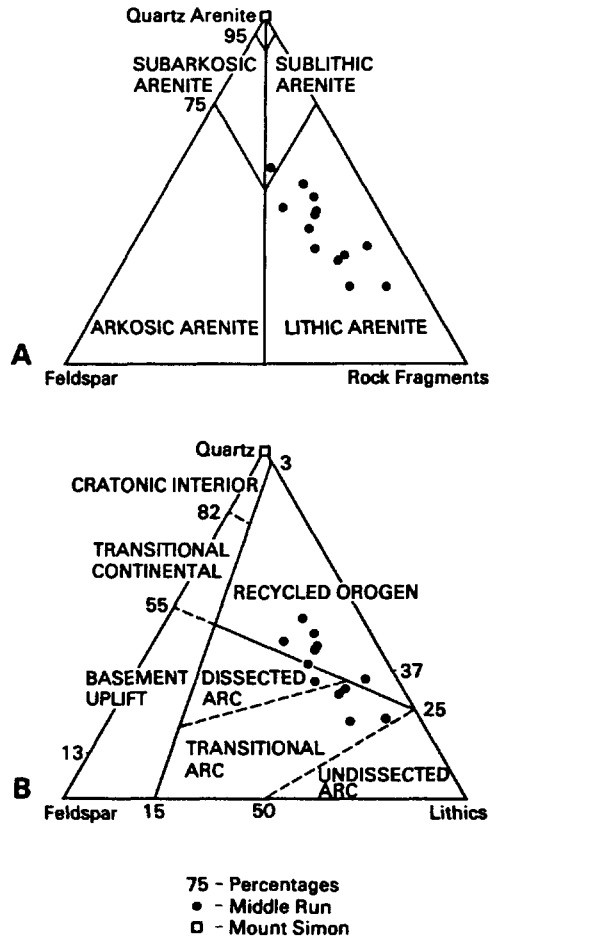

FIGURE 5. Petrographic triangle diagrams. A, composition of Middle Run Formation; B, provenance of Middle Run Formation (after Dickinson 1984, Fig. 1).

Wisconsin (Ojankangas and Morey 1982, Dickas 1986, Wollensak 1988) are also possible correlatives for the Middle Run. These correlations are tentative and further research is necessary to prove or disprove the postulated correlation of the Middle Run Formation to the rift-related sediments in Michigan and elsewhere.

Depositional Environment

Sedimentary features in the formation, such as thin to thick crossbedding, fine horizontal and ripple laminations, and massive intervals, imply a fluvial depositional environment (Olsen 1988) for the Middle Run Formation (Fig. 2). Also, the moderately well sorted sedimentologic framework is petrographic evidence of a fluvial origin. The lack of abundant conglomerates combined with the appearance of the Middle Run Formation on the seismic profile as a thick, uniform fill, (inferred from the weak, internal, poorly defined reflectors), may indicate deposition by a longitudinal stream rather than by coalescing fans along the sides of the basin. The presence of an arid climate during the deposition of the Middle Run is implied by the presence of calcite cement, nodules, mottles, and veins. The calcite in the Middle Run may possibly have been formed in a manner equivalent to the caliche or pedogenic nodules present in the Miocene Rio Grande rift-fill in New Mexico (Cavazza 1989), or to the caliche or vadose carbonate in the rift-fill sediments of Michigan's Upper Peninsula (Kalliokoski 1988a). The presence of hematitic cement and rims on grains (Almon 1981) in the Middle Run may be indicative of it having been deposited in a semi-arid to arid climate.

Provenance of the Middle Run Formation

The sedimentary material composing the Middle Run Formation has a provenance indicative of a mixed metamorphic-silicic volcanic source with minor sedimentary rocks. Using the method of Dickinson (1984) for determining provenance, the Middle Run Formation would be chiefly derived from a recycled orogen with some affinities to a dissected or transitional arc (Fig. 5B). Most likely, the clastic material was derived from the erosion of the Grenville orogenic belt to the east and from the erosion of the Eastern Granite-Rhyolite Province to the west.

Age of the Middle Run Formation

On the basis of the stratigraphic occurrence of the Middle Run Formation in Ohio, its sedimentologic similarities to other Precambrian red clastic sequences, and the possibility that it is structurally related to the Grenville Orogeny, a relative age of Late Precambrian (Keweenawan) is tentatively proposed for the Middle Run Formation. Alternatively, the formation can be only as young as the earliest Late Cambrian on the basis of its position beneath the Late Cambrian-age Mount Simon Sandstone.

ACKNOWLEDGEMENTS. The successful completion of the Warren County core hole and the seismic profile was possible only with the generous contributions and support of the following individuals and businesses. Drilling contributors: Ashland Exploration, Inc.; Belden & Blake Corp.; Columbia Natural Resources, Inc.; CNG Development Co.; Dr. Richard H. Durrell; Lomak Petroleum (OH), Inc.; Paragon Geophysical Inc.; Petro Evaluation Services, Inc.; Quaker State Corp.; and, Stone Resources and Energy Corp. Seismic contributors: Cincinnati Gas & Electric Co.; Dayton Power & Light Co.; Columbia Natural Resources, Inc.; Hosking Geophysical Corp.; Paragon Geophysical Inc.; Stocker & Sitler, Inc.; Strata Search, Inc.; Stroder & Unruh Geophysical Corp.; Woods Geophysical, Inc.; and, Unocal, Inc.

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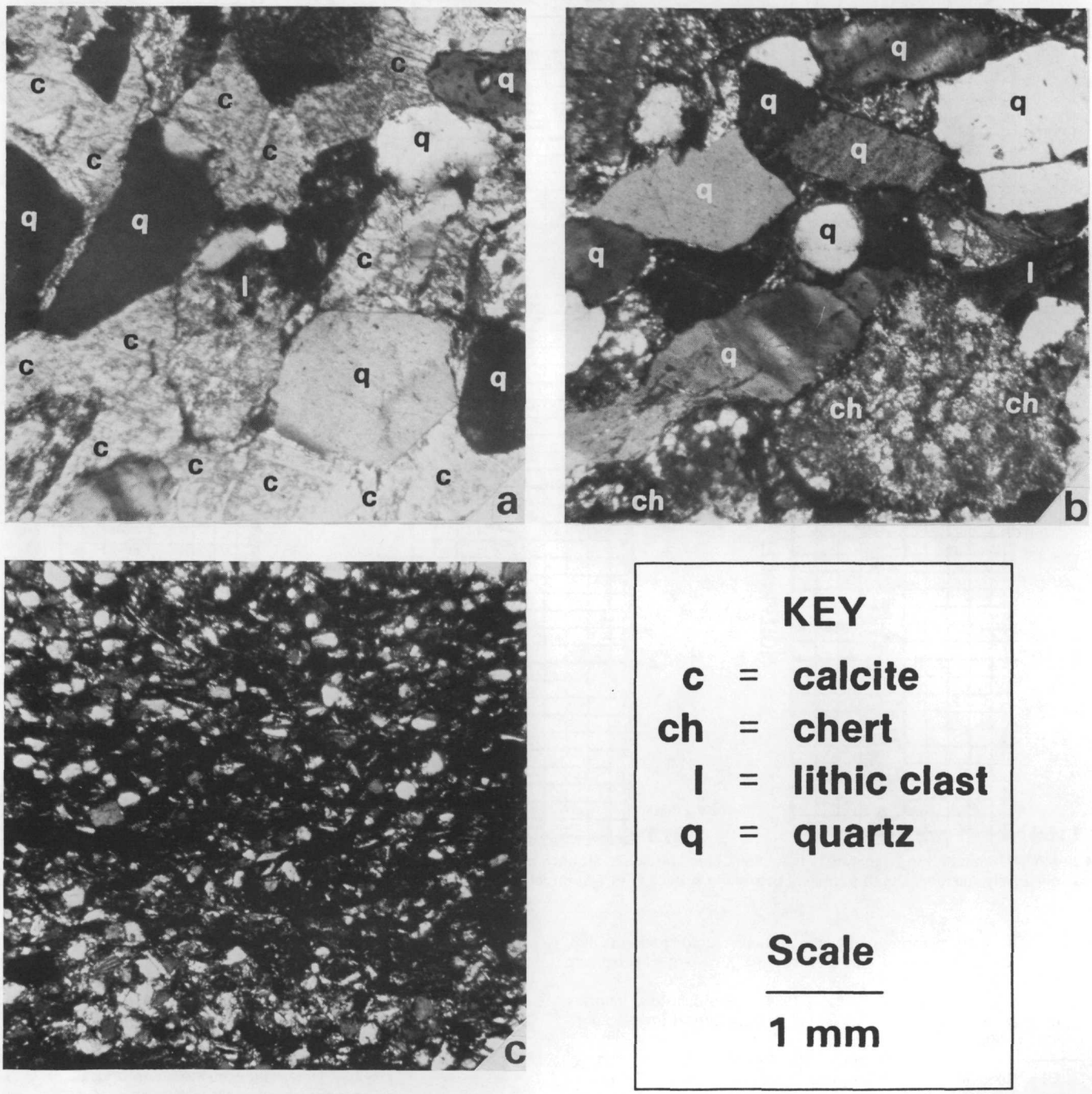

FIGURE 6. Photomicrographs of thin-sections of the Middle Run Formation lithologies. a, example of poikilotopic cement from 1257 m; b, example of densely compacted, cement-free arenite from 1118 m; c, example of sandy siltstone from 1477 m.

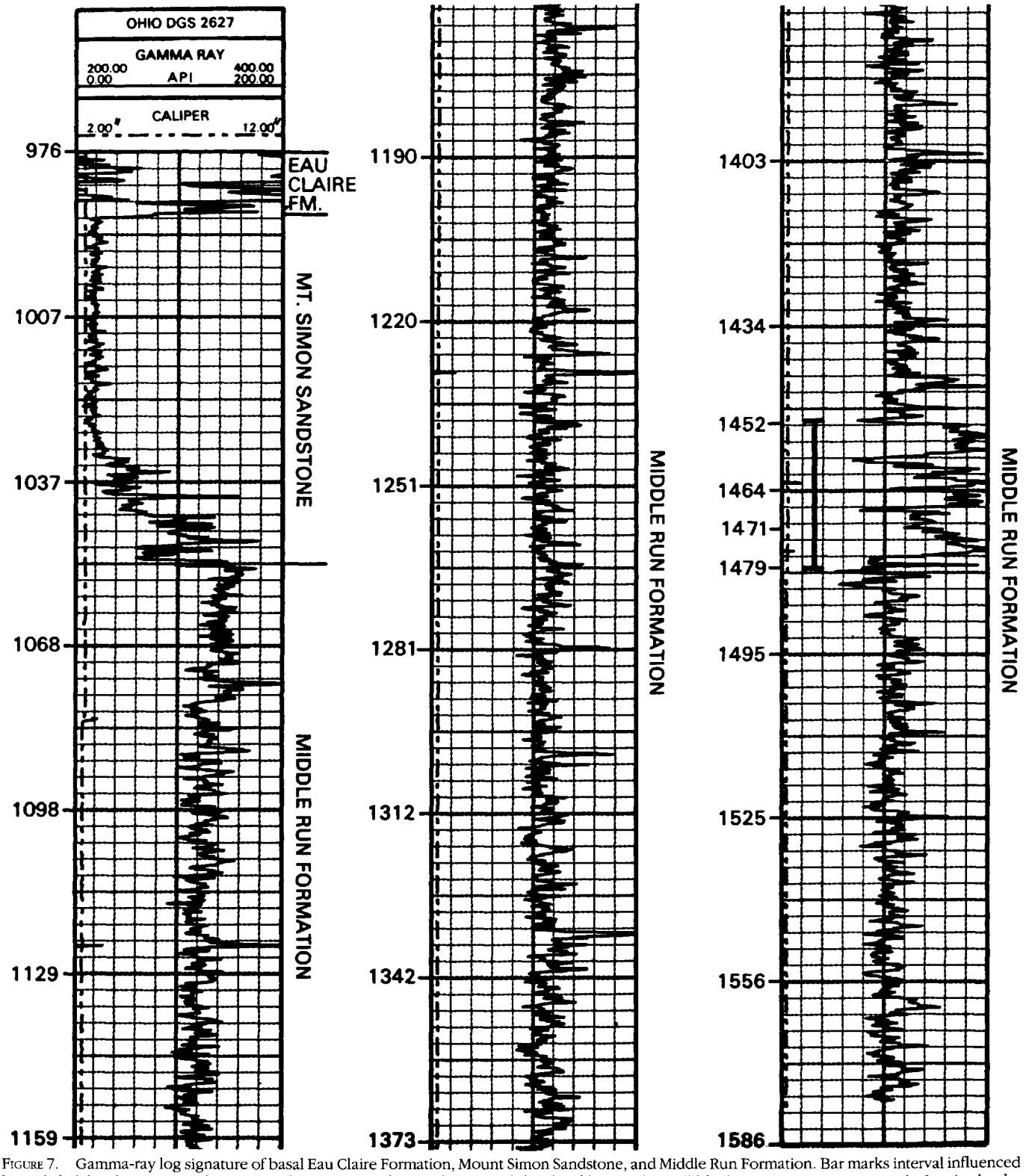

FIGURE 7. Gamma-ray log signature of basal Eau Claire Formation, Mount Simon Sandstone, and Middle Run Formation. Bar marks interval influenced by red-shalely siltstone. Depth in meters below the surface is shown on left side of log. Each small block represents approximately 3 m in depth.

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APPENDIX

THE MIDDLE RUN FORMATION

INTERVAL 1055-1471 m sandstone (lithic arenite), grayish-red (5 R 4/2) to grayish-red-purple (5 RP 4/2) to moderate-red (5 R 4/6), fine- to medium-grained, moderately well to moderately poorly sorted, subangular to subrounded-grained; siliceous, calcareous, and hematitic cements; calcite cement in irregular, light-gray (N 8), nodules and masses with diffuse boundaries or veins, masses or mottles with distinct boundaries; based on the neutron-porosity log, porosity ranges from 0.3% to 4.8%, and averages 1.6% (personal communication, Amoco Oil Company 1990).

Calcite cement is predominant where subangular to subrounded, granule- to pebble-sized clasts are present, forming thin, poorly sorted conglomerates (Fig. 6a). Sedimentary features include finely-spaced horizontal and ripple laminae, low-angle crossbeds, and massive beds. Upper contact is sharp, erosional; lower contact is not present, but estimated from seismic data to be at approximately 2,100 m.

Petrographically, quartz content ranges from 29% to 46%, and averages 34%. Monocrystalline quartz is six times more abundant than polycrystalline quartz. Feldspar content ranges from 14% to 21%, and averages 16%. Perthite grains are common; microcline grains are rare. Potash feldspar is about four times as abundant as plagioclase. Fresh and altered grains of feldspar are present. Lithic content averages 42%. Metamorphic grains include foliated intergrowths of quartz, micas and feldspars, micaceous schists, and some epidote-enriched grains. Volcanic grains are aphanitic, have a crystallized, chertlike groundmass, and contain scattered, in some cases embayed, quartz crystals. Weakly birefringent, fine-sized polycrystalline grains also are considered volcanic. Intergranular porosity is about 0.5%. Sedimentary grains include siltstone, sandstone, scattered carbonate grains, and shales. Plutonic grains are primarily granite. Micas (biotite, muscovite, and chlorite) are abundant in fine-grained, tightly compacted intervals (Fig. 6b). Heavy mineral grains account for about 1% of the framework.

Gamma-ray log signature has higher API values and more variable than that of the overlying Mount Simon Sandstone (Fig. 7).

INTERVAL 1471-1479 m siltstone, dark-reddish-brown (10 R 3/4), silty- to very fine grained; moderately well to well sorted; siliceous cement with calcite-rich laminae; quartz grains predominant with minor amounts of fine-grained lithic clasts; hematitic matrix; iron-magnesium minerals disseminated in places; with lenses and bands of siltstone, possibly diagenetically altered to light-gray (N 8); no visible porosity in thin section or on the neutron porosity log (Fig. 6c).

Sedimentary features include calcite nodules or bands, slickensides, graded bedding, and laminations. Contact with overlying and underlying sandstone is generally sharp.

Gamma-ray log signature between 1452-1479 m is quite distinct because it exhibits higher API values than the rest of the Middle Run (Fig. 7). The difference is attributed to clasts or thin partings from the shalely-siltstone layer between 1471-1479 m, or possibly a similar deposit elsewhere in the basin, being incorporated into this interval. The interval delineated by the bar on the geophysical log is believed to be the seismic reflector shown in Fig. 2.

INTERVAL 1479 to 1581 m sandstone (lithic arenite), as in interval 1055-1471 m.

INTERVAL 1581-1582 m conglomerate, angular, pebble- to cobble-sized clasts of moderate red (5 R 4/6) (common) and dark-greenish-gray (5 G 4/1) (rare) siltstone and silty shale, intensely fractured (brecciated). Because of the collapse of this interval and the resultant lodgment and abandonment of the drill string at this point, geophysical logs begin immediately above this interval.

INTERVAL 1582-1638 m sandstone (lithic arenite), as in interval 1055-1471 m. Geophysical tools unable to reach total depth because of drill string abandoned in the core hole in preceding interval.