Geological Survey
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To Accompany IC-6

PALEOZOIC LITHOSTRATIGRAPHIC NOMENCLATURE FOR SOUTHEASTERN MINNESOTA

by

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INTRODUCTION

The Paleozoic lithostratigraphic nomenclature shown in the column was compiled from information obtained from several sources—outcrops, deep cores, and theses on the geology of southeastern Minnesota. It is a revision of the Paleozoic stratigraphic column published in 1956 (Schwartz, 1956). The purpose of this discussion is to describe the Paleozoic strata of southeastern Minnesota in terms of the revised nomenclature and to call attention to related post-1956 publications and other source materials.

PRE-MT. SIMON ROCKS

Several types of older rocks, mainly Keweenawan in age, lie directly beneath the Mt. Simon Sandstone in southeastern Minnesota. These are principally the Hinckley Sandstone and arkosic sandstones and shales, considered to be Upper Keweenawan in age, and basalt and rhyolite flows of Middle Keweenawan age. Older granitic rocks directly underlie the Mt. Simon both to the west and east of the relatively thick section of Paleozoic rocks in the Paleozoic basin herein called the Hollandale Embayment (See index to locations with accompanying diagram).

The Hollandale Embayment was a shallow depression that extended northward from the Forest City Basin proper onto the cratonic shelf and into Minnesota and Wisconsin in early Paleozoic time. The marine rocks that now remain within the embayment are bordered to the east by the near-shore-facies Paleozoic rocks on the Wisconsin Arch and to the northeast, north, and west by the Precambrian rocks that constitute the Wisconsin Dome and the Transcontinental Arch. The strata have been eroded from all but the central part of the original embayment, but originally they probably extended some distance beyond to the north and west (Parham and Austin, 1967 and 1969). The embayment overlies older basins and horsts that are bounded by large-scale Precambrian faults (Sims and Zietz, 1967), but the pre-Mt. Simon rocks for the most part form an older, smaller basin which has been cut by large-scale faults. Relatively minor recurrent movements along these faults during Paleozoic time have resulted in a complex depositional and post-depositional history of the Paleozoic rocks in the Hollandale Embayment. Many smaller Paleozoic basins, depositional barriers, and faults within the embayment probably have resulted from renewed activity along Precambrian structures (Craddock, Thiel and Gross, 1963).

As the Upper Cambrian seas transgressed over older rocks within the embayment, the Mt. Simon Sandstone was deposited on the Red Clastic Series to the south and on the Red Clastic Series and Hinckley Sandstone near the Twin City Basin. To the northeast, pre-Mt. Simon sedimentary rocks lie directly beneath green sandstone and siltstone (Sims and Zietz, 1967) of the Eau Claire Formation, and in the valley of the St. Croix River, a basalt-boulder conglomerate above Middle Keweenawan basalt contains the *Elvinia* fauna (Nelson, 1956) of Franconian age.

The pre-Mt. Simon granites, flows and sedimentary rocks are identified as Precambrian and all but the granitic rocks have been considered Keweenawan. Recently Ostrom (1967) suggested that the arkosic and lithic rocks of the Oronto Group of northern Wisconsin and the upper peninsula of Michigan may be Cambrian in age. Ostrom (1967) tentatively assigned the Bayfield Group, which lies above the Oronto Group, to the Cambrian System. Kirwin (1963) and Tyler and others, (1940) correlated the Fond du Lac Formation of Minnesota and Wisconsin with the lower part of the Bayfield Group, the Hinckley Sandstone with the middle part of the Bayfield Group, and the more arkosic and lithic sandstones below the Fond du Lac with the Oronto Group. Kirwin (1963) tentatively correlates the Fond du Lac Formation, the Hinckley Sandstone, and the underlying sedimentary rocks with lithologically similar units encountered in the subsurface in southeastern Minnesota. These rocks are referred to as the Red Clastic Series (Meinzer, Hall and Fuller, 1911).

The Minnesota Geological Survey prefers to consider these units as Keweenawan for the following reasons: (1) The Red Clastic Series and its surface equivalents lack worm burrows and other evidences of macroscopic life, (2) they are locally highly deformed in southeastern Minnesota (Austin, 1969), whereas the overlying Paleozoic rocks are nearly flat-lying, (3) the Upper Cambrian rocks lie unconformably on older rocks, which locally have been deeply weathered, and (4) the pre-Mt. Simon rocks have been down faulted several thousand feet (Sims and Zietz, 1967); faulting on this scale is not known in the Paleozoic rocks of the continental interior.

PALEOZOIC FORMATIONS

Mt. Simon Sandstone

The Mt. Simon Sandstone is composed of white, gray, pink or locally yellow, medium-grained sandstone and some thin shale beds. Fine-grained sandstone near the top of the unit and coarse-to very coarse-grained sandstone toward the bottom are interbedded with medium-grained sandstone. The Mt. Simon is a quartzose sandstone but may contain siderite, particularly near the base. Many cross-bedded zones and numerous fragments of inarticulate brachiopods, especially near the top, indicate a high-energy depositional environment. However, the thin grayish-green shale beds which are especially common in the upper part of the formation and are interstratified with these high-energy deposits, indicate the periodic development of lower energy environments of deposition. The most recent published description of this formation is included in an article on Upper Cambrian rocks in Minnesota by Berg, Nelson, and Bell (1956). However, the Mt. Simon, Eau Claire, and Galesville Members of the Dresbach Formation (Berg, Nelson, and Bell, 1956) herein are elevated to formational status in recognition of their lateral continuity.

Eau Claire Formation

The Eau Claire Formation consists of five different rock units in Minnesota. A "red shale phase" (Stauffer, 1927; Stauffer and Thiel, 1941) – more properly classified as a red, silty, fine-grained sandstone and shale or red, locally worm-bored siltstone–occurs along the western border of the Hollandale Embayment and below the other rock types of the formation near the center of the embayment (Austin, 1969). Fine-grained non-glauconitic sandstone and interbedded grayish-green fissile shale are found in the lowest part of the Eau Claire where the red unit is absent. Glauconitic, very fine- to medium-grained sandstone with some thin grayish-green shale beds characterize the middle unit of the formation. Inter-bedded grayish-green shales and fine-grained sandstones comprise the fourth rock type. The thickest shale bed that has been noted in this unit is about 8 feet thick. The fifth and uppermost unit is a massive light-gray, locally slightly glauconitic, fine-grained sandstone with some interbedded shale.

Galesville Sandstone

The Galesville Sandstone in Minnesota is a white to light-gray, slightly glauconitic, well- to moderately well-sorted, mostly medium-grained sandstone but interbedded with fine-grained sandstone beds toward its base. The base is placed just below the first medium-grained sandstone and just above the massive fine-grained sandstone that is typical of the upper part of the Eau Claire Formation. In western Wisconsin, the Galesville lies disconformably on the Eau Claire (Ostrom, 1966).

Ironton Sandstone

The Ironton Sandstone is a white, medium-grained, moderately well-to poorly-sorted sandstone that has a significant amount of admixed silt-size material. The top few feet contain some glauconite and are typically stained yellowish-brown on the outcrop in contrast to the dominant white or light-gray color of the bulk of the formation. The base of the Ironton is placed just above the non-silty, better sorted, medium- and fine-grained sandstones of the Galesville and just below the silty, less well-sorted, medium-grained sandstones of the Ironton.

Berg (1954) and Berg, Nelson, and Bell (1956) identify an unconformity at the base of the Ironton which separates the regressive Galesville from the transgressive Ironton. The Ironton Sandstone is more properly classified as a lower energy sandstone that lies above the higher energy Galesville. In accordance with this view, a reversal from regressive to transgressive deposition is present within the Galesville. Where the entire Galesville-Ironton succession is present, as near the center of the Hollandale Embayment, the bottom part of the Galesville is regressive and the upper part is transgressive. Away from the center of the embayment, as on the Wisconsin Arch, only the upper transgressive Galesville is present and an unconformity is present between the underlying Eau Claire Formation and the overlying Galesville Sandstone (Ostrom, 1966). The Ironton Sandstone was deposited in quieter and deeper water. Sand from the same source as the Galesville, and therefore of the same grain size, was deposited during Ironton time. The sandstone of the Ironton, however is less well-sorted than the Galesville and commonly contains silt. Bottom currents of lower energy could not sort grains as efficiently as those of Galesville time. The contact between Ironton and Galesville Sandstones may be sharp due to a rapid change in current activity. The abrupt current change in the St. Croix Valley may have resulted from movement along Precambrian faults in Cambrian time; this movement also produced the unconformity between the Galesville and Ironton noted by Berg (1954) and Berg, Nelson, and Bell (1956).

Berg (1954) renamed the Ironton of Ulrich (1924) as the Woodhill because he considered the name "Ironton" too closely tied to the *Elvinia* fauna. Subsequently, this interpretation has been discredited (Buschbach, 1964, and Ostrom, 1967), and accordingly "Ironton" is reinstated herein. Berg (1954) considered the unit a member of the Franconia Formation. In Wisconsin, Ostrom (1965, 1966, and 1967) placed both the Ironton and Galesville in the Wonewoc Formation inasmuch as it is difficult and impractical to distinguish one from the other or to identify their contact in that area. Because the higher energy nature of the Galesville and the lower energy nature of the Ironton are more easily recognizable in Minnesota away from the Wisconsin Dome, the Minnesota Geological Survey prefers to maintain the Galesville and Ironton Sandstones as separate formations. Both units have been designated formations because of their substantial lateral continuity in Minnesota.

Franconia Formation

The Franconia Formation contains four members. In ascending order, they are the Birkmose Member, a glauconitic, worm-bored, fine-grained sandstone containing some silt and some dolomitic layers; the

Tomah Member, a very fine- to fine-grained, locally glauconitic, silty sandstone with some interbedded greenish-gray micaceous shale and minor amounts of glauconitic dolomite; the Reno Member, a glauconitic, worm-bored, fine-grained sandstone; and the Mazomanie Member, a thin-bedded or cross-bedded, essentially non-glauconitic, dolomitic, fine- to coarse-grained sandstone that interfingers with and replaces the Reno and Tomah Members in the northern St. Croix Valley. Descriptions of the four members of the Franconia have been given by Berg (1954).

The Mazomanie is present in the northern part of the Twin City Basin and to the north and east. The Reno constitutes nearly the entire Franconia section along the Mississippi River Valley in Minnesota but disappears toward the center of the Hollandale Embayment (Austin, 1969). The Tomah is the most laterally persistent member of the formation and is the only member present at places near the center of the embayment. The base of the Franconia Formation is placed just above the highest essentially non-glauconitic, medium-grained sandstone of the Ironton and just below the commonly glauconitic, fine-grained sandstones of the Franconia.

St. Lawrence Formation

The St. Lawrence Formation contains a variety of silty and sandy dolomitic rocks that lie between the overlying Jordan Sandstone and the underlying Franconia Formation. The most recent publication on the St. Lawrence in Minnesota and western Wisconsin is by Nelson (1956). McGannon (1960), in an extensive unpublished sedimentologic and petrographic study of the formation, has pointed out many problems in Nelson's interpretation of the unit. The Minnesota Geological Survey prefers to use Nelson's names for the members of the St. Lawrence, but has adopted McGannon's descriptions of the members for official use.

The lower member of the St. Lawrence Formation, the Black Earth Member, is composed of glauconitic, argillaceous, silty or sandy dolomite; the dolomite content of the member exceeds 70 percent. The Black Earth is highly resistant for the most part but does contain some less resistant silty beds. Flat-pebble conglomerates occur in the member and are particularly common near the base (McGannon, 1960; Twenhofel, Raasch and Thwaites, 1935). The lower contact of the member is placed just above the sandstone beds of the Franconia Formation, which may be dolomitic and conglomeratic, and below the lowest, highly dolomitic, resistant bed of the Black Earth Member. The Black Earth thins northward and is absent at the most northerly exposures of the St. Lawrence in the valley of the St. Croix River, where the upper member of the St. Lawrence lies directly on the underlying Franconia Formation. Near the center of the embayment and to the west, the Black Earth makes up the entire St. Lawrence succession.

The upper or Lodi Member of the St. Lawrence Formation is composed of silty argillaceous dolomite; the dolomite content is less than 70 percent except locally at the top of the unit. The lower part of the Lodi contains mottled green, slightly glauconitic, argillaceous dolomite, which is less resistant than the Black Earth Dolomite, and buff dolomitic siltstones or alterations of these types. The upper Lodi consists of unmottled buff or gray, thin- to thick-bedded, hard, argillaceous, silty dolomite, with some units of white or brown, friable to well-cemented, sandy siltstone. The upper Lodi may contain a trace amount of glauconite. The Lodi generally makes up the entire thickness of the St. Lawrence Formation on the Wisconsin Arch and in the Mississippi River Valley, whereas in the center of the embayment only the Black Earth is present. The contact between the Lodi and the overlying Jordan Sandstone is placed at the point where the dominant dolomite or siltstone of the Lodi is overlain by the dominant sandstone of the Jordan. This contact may be difficult to locate where the fine-grained sandstone of the Norwalk Member of the Jordan overlies siltstones of the Lodi Member of the St. Lawrence Formation.

Jordan Sandstone

The Jordan Sandstone in Minnesota contains three members. In ascending order these are the Norwalk Member, a yellow, silty, fine-grained sandstone; the Van Oser Member, a white or yellow, coarse-to medium-grained, quartzose sandstone; and the Sunset Point Member, an argillaceous and dolomitic sandstone with pebble-sized clasts of dolomitic sandstone and thin beds of dolomite. The Van Oser is the thickest and most laterally persistent member of the Jordan Sandstone in Minnesota and probably is the only member present in the Twin City Basin. The Sunset Point Member occurs principally along the Mississippi Valley, and the Norwalk Member is confined to the fringes of the Hollandale Embayment in Minnesota. The dolomitic Sunset Point Member foreshadows the thick dolomites of Early Ordovician age in Minnesota. At the type locality in Madison, Wisconsin, the member is a dolomite and yields Cambrian fossils (Raasch, 1952). The Sunset Point in the Mississippi Valley is primarily a dolomitic sandstone but does contain some dolomite beds (Ostrom, 1965).

Prairie du Chien Group

The Lower Ordovician rocks are difficult to differentiate in southeastern Minnesota (Heller, 1956). Accordingly, where the underlying Oneota Dolomite cannot be separated from the overlying Shakopee Formation, it is advisable to identify the entire succession as the Prairie du Chien Group.

Oneota Dolomite

The Oneota Dolomite is primarily a thin- to thick-bedded, locally stromatolitic, light-brownish-gray or buff, fine- to medium-grained dolomite with a silt-size dolomite matrix. Chert and some sand-sized detritus occur locally near the base of the formation. A greenish-gray shaly siltstone locally present beneath the dolomite is designated the Blue Earth Siltstone Beds of the Oneota Dolomite. A thin sandstone unit lithologically similar to the underlying Jordan Sandstone but containing Ordovician fossils (Powell, 1935) is present locally beneath the Blue Earth Beds and is designated the Kasota Sandstone Beds of the Oneota Dolomite . The Sunset Point Member of the Jordan Sandstone and the Blue Earth siltstone and Kasota Sandstone Beds of the Oneota Dolomite illustrate facies changes across the Cambro-Ordovician boundary, with carbonate deposition beginning in the east in Wisconsin during latest St. Croixan time and clastic sediments from terrestrial sources being deposited in the west in Minnesota during earliest Canadian time.

Shakopee Formation

The Shakopee Formation consists of two members (Davis, 1966a). The lower member, the New Richmond Sandstone, consists of fine- to medium-grained quartzose sandstone and quartzitic dolomite and minor amounts of shale and pure dolomite. The upper boundary of the member commonly is marked by a thin zone of interbedded grayish-green shale, quartzose sandstone and dolomite. The New Richmond Sandstone in Wisconsin and extreme southeastern Minnesota lies on truncated Oneota (Ulrich, 1924; Ostrom, 1965; Davis, 1966a and 1966b). The New Richmond is thin and not distinguishable from the thin sandstone beds within the upper member of the Shakopee Formation west of the Red Wing-Rochester anticline. The upper member of the Shakopee Formation, the Willow River Dolomite, consists of thin- to thick-bedded dolomite, sandy dolomite, some interbedded quartzose sandstone, and some grayish-green shale. Chert and algal stromatolites commonly are present in the Willow River Member.

St. Peter Sandstone

The St. Peter Sandstone is a light yellow or white, medium-grained but locally fine-grained, massive-appearing, generally well-sorted, quartzose sandstone composed of rounded and subrounded grains. Because of its uniform grain size and low content of minerals other than quartz, cross-bedding is rarely observed in outcrop. A few thin beds of green shale are present within the formation, and the bottom few feet locally may be silty and contain some shale. The large-scale relief on the erosional unconformity at the base of the St. Peter in Wisconsin (Ostrom, 1965 and 1967) does not seem to be present in Minnesota, and the contact between the St. Peter and the Shakopee Formation may be even gradational in the center of the embayment.

The lower part of the St. Peter has been described as shaly in Minneapolis (Thiel, 1944). Studies of cuttings from several wells in the western suburbs where the St. Peter is the thickest indicate, however, that the supposedly shaly St. Peter is probably the New Richmond Member of the Shakopee Formation. Below this shaly sandstone are thin sandy dolomites and interbedded sandstone, shales, and dolomites which are identified as shoreward equivalents of the Oneota Dolomite.

Glenwood Formation

The Glenwood Formation is composed of grayish-green or yellow shale and a basal argillaceous sandstone. A few local beds of limestone or dolomite also may be present. The Glenwood in the past was separated from the Platteville Formation or St. Peter Sandstone and elevated to formational status (Weiss and Bell, 1956; Ostrom, 1969). The Minnesota Geological Survey prefers not to divide the Glenwood into members as has been done in Illinois (Templeton and Willman, 1963) and in Wisconsin (Ostrom, 1969). The lower contact is placed between the massive white sandstone of the underlying St. Peter and the argillaceous sandstone of the overlying Glenwood. The upper contact is placed above the uppermost thick shale bed and below the first massively bedded, commonly sandy, dolomitic limestone of the Platteville Formation.

Platteville Formation

The Platteville Formation consists of three members. The lower or Pecatonica Member is a yellowish brown, medium- to fine-grained dolomite or dolomitic limestone which may be sandy, particularly at the base. The sandy texture is a result of the presence of medium to fine-grained, rounded quartz sand. The Pecatonica Member commonly contains several corrosion zones in Minnesota. The middle or McGregor Member is a gray, light olive gray, or buff, fine-to very fine-grained, thin-bedded, dolomitic limestone or dolomite with interbedded brown or olive green shale. The McGregor has rippled bedding surfaces, which give it a characteristic crinkly bedding. The upper or Carimona Member is a medium-bedded, fine-grained, light olive gray or buff limestone with interbedded olive gray shale. A generally 0.1 to 0.2-foot-thick bentonite, the "Carimona bentonite," is found at or just above the Carimona-McGregor contact. In the past, the interval occupied by the McGregor Member in most of southeastern Minnesota has been divided locally into members, primarily in the Twin City Basin (Weiss and Bell, 1956; Rassam, 1967). In ascending order these are the Mifflen, a very thin and crinkly-bedded limestone, which is about 11 to 13 feet thick in the Twin City Basin; the Hidden Falls, a very argillaceous, dolomitic limestone about 6 feet thick; and the Magnolia, a micro-granular dolomitic limestone or calcareous dolomite which is thicker bedded and less argillaceous than is typical of the McGregor. Because these units are thin and of a local nature within the thicker, more extensive McGregor Member, the Minnesota Geological Survey prefers to use these units as submembers of the McGregor Member.

Decorah Shale

The Decorah Shale is a greenish-gray or olive gray, fissile, fossiliferous shale that contains scattered limestone beds which are commonly coquinoidal in Minnesota. For practical purposes, the lower contact is placed above the lowest non-coquinoid carbonate bed of the Platteville and below the first thick shale bed of the Decorah. Parham and Austin (1969) have indicated, however, that the contact at places may be a shale-on-shale type, with Decorah shale lying directly on Carimona shale. Because such a contact is difficult to identify in the field, it is preferable to place the contact at the lithologic break previously used. In Minnesota, the Decorah Shale has been divided with difficulty into members on the basis of lithologic differences (Agnew, 1956; Weiss and Bell, 1956). Because the formation is essentially a shale in Minnesota, the Minnesota Geological Survey prefers to identify the unit as the Decorah Shale and does not subdivide it into members.

Galena Formation

The Galena Formation in southeastern Minnesota contains three members. In ascending order they are the Cummingsville Member, the Prosser Member, and the Stewartville Member. The Cummingsville is composed of interlayered thick beds of light olive gray or buff limestone and thinner beds of both fissile and massive greenish-gray shale. The Prosser contains gray thin- to medium-bedded limestone or dolomitic limestone and has a small detrital component (Weiss and Bell, 1956; Weiss 1957). The Stewartville Member is a buff-weathering, grayish-yellow, fine- to medium-grained dolomitic limestone that has a conspicuous mottled appearance. Although the units within the Galena Formation are considered members, the lithotopes are known to have alternated, producing interfingering lithologies (Austin, 1969).

Dubuque Formation

Interbedded light olive gray or grayish-yellow, medium-bedded, crinoidal, fine-grained limestone and gray shale comprise the Dubuque Formation in Minnesota. The lower contact is placed above the mottled Stewartville and below the first shale bed of the Dubuque. The upper contact is placed above the highest shale and crinoidal limestone beds of the Dubuque and below the shaly dolomite and dolomitic limestone beds of the Maquoketa Formation. The lowest Maquoketa beds generally carry graptolite fragments.

The Dubuque Formation is tentatively correlated with the Cincinnatian formations Eden-Maysville age of Ohio and Kentucky on the basis of conodont assemblages (G. F. Webers, oral communication, 1969), although data from the study of Ostracodes (Burr and Swain, 1965) indicate that this correlation is questionable.

Maquoketa Formation

Two members comprise the Maquoketa Formation in Minnesota (Bayer, 1965). The lower or Elgin Member contains flaggy limestones with nodular calcareous shales, shaly dolomite and calcareous shale beds, and coarsely crystalline dolomitized limestone. The upper or Clermont Member is a tan sandy limestone. The remainder of the Ordovician Maquoketa Formation in Minnesota was eroded prior to the deposition of the Cedar Valley Formation during Devonian time. The stratigraphy of the Maquoketa in Minnesota closely corresponds to that of the lower part of the Maquoketa in northern Iowa (Parker, Dorheim, and Campbell, 1959). The Maquoketa in Minnesota, however, does not contain the distinctive "depauperate beds" which are characteristic of the Maquoketa in Iowa (Glenister, 1957), and there is quite probably no break in deposition between the Dubuque and Maquoketa Formations as is present in Iowa.

Cedar Valley Formation

The Cedar Valley Formation consists of three members in Minnesota (Kohls, 1961). In ascending order they are the Solon Member, the Rapid Member, and the Coralville Member, as defined by Stainbrook (1941). The Solon Member is transitional from a buff-gray, fine-grained, biogenic dolomite at the base to a light buff-gray, sublithographic dolomitic limestone toward the top. The Rapid Member is composed of gray, fine-grained, shaly dolomite with prominent microbedding and black streaks of finely divided pyrite. The Coralville Member contains lithographic high-calcium limestone with microbedding and buff-gray, fine-to medium-grained dolomite and calcitic dolomite. Collinson and others (1967) have placed the Cedar Valley Formation of northern Iowa in the upper Middle Devonian. The formation was deposited during the Tioughniogan and Taghanic stages (Collinson and others, 1967).

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