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GEOLOGIC RESOURCES

By

Dale R. Setterholm and Howard C. Hobbs

1998

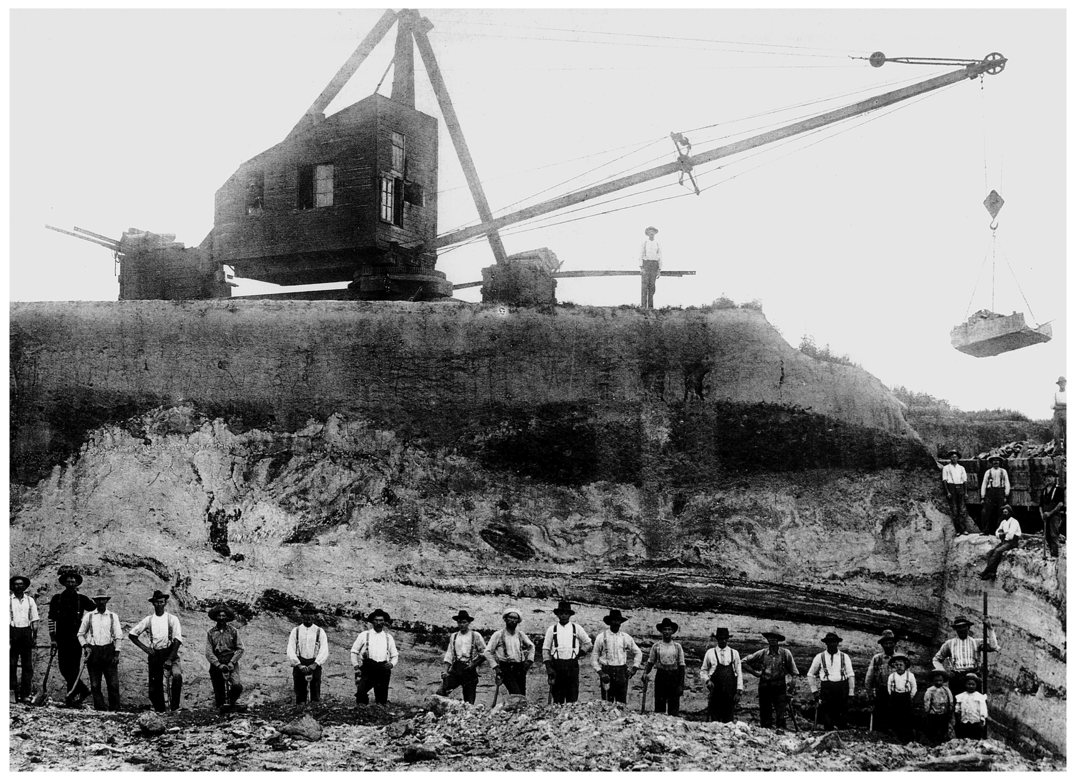
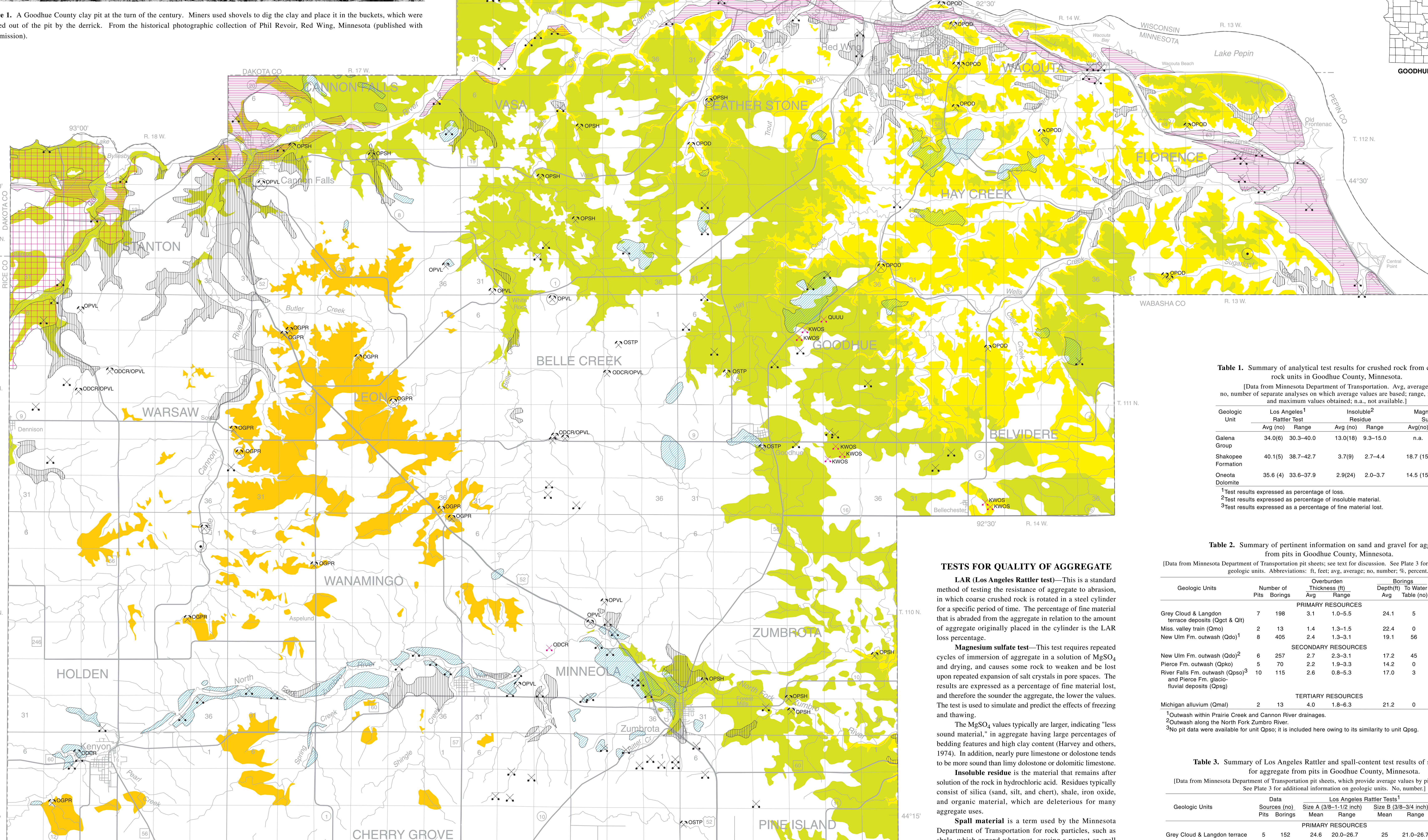


Figure 1. A Goodhue County clay pit at the turn of the century. Miners used shovels to dig the clay and place it in the buckets, which were lifted out of the pit by the derrick. From the historical photographic collection of Phil Revoir, Red Wing, Minnesota (published with permission).



Digital base modified from 1990 Census TIGER/Line Files of U.S. Bureau of the Census (source scale 1:100,000); county border files modified from Minnesota Department of Transportation files; digital base annotation by Minnesota Geological Survey

Universal Transverse Mercator Projection, grid zone 15
1927 North American Datum

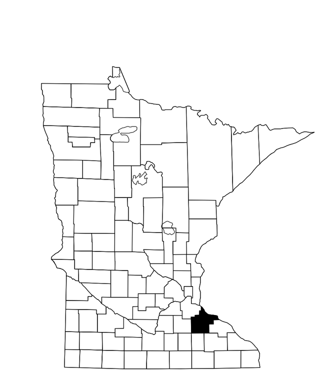
SCALE 1:100 000

1 0 1 2 3 4 5 MILES

1 0 1 2 3 4 5 6 7 8 KILOMETERS

Bedrock resources compiled by Dale R. Setterholm
Quaternary resources compiled by Howard C. Hobbs

GIS compilation and cartography by
Joyce Meints and Philip Heywood



DESCRIPTION OF MAP UNITS AND SYMBOLS

Carbonate Rock Resources

To have value as a resource, carbonate rocks must be reasonably thick (30 feet or more) and not deeply buried. The map shows where carbonate rock is the uppermost bedrock and the thickness of overlying deposits is less than 50 feet thick.

Galena Group—Although parts of the Galena Group produce aggregate suitable for use in concrete, its content of insoluble residue is too high for use in bituminous pavement. The Cummingsville Formation has abundant interbedded shale, especially in its lower half, which makes it unsuitable for some uses. The Prosser Limestone is the part of the Galena Group most likely to provide a significant resource.

Shakopee Formation—Material from the Shakopee Formation will commonly fail to meet paving standards. A Los Angeles Rattler (LAR) test value of 40 percent or less is required for use in concrete or bituminous paving.

Oneota Dolomite—Some material from the Oneota Formation meets the requirements for use in concrete and bituminous paving, but some samples fail the magnesium sulfate requirements

Rock quarry—Symbol represents active and inactive pits. The mined rock unit is indicated by a four-letter code (the codes are those used in the County Well Index data base to identify geologic units).

- OGPR Prosser Limestone (Galena Group)
- ODCR Decorah Shale
- OPVL Platteville Formation
- OSTP St. Peter Sandstone
- OPSH Shakopee Formation
- OPOD Oneota Dolomite

Chemical analyses—As reported in Niles and Mossler (1988).

Quarry

Outcrop

Clay Resources

Clay pit—Symbol represents active and inactive pits. The mined deposit is indicated by a four-letter code (the codes are those used in the County Well Index data base to identify geologic units).

- QUUU Quaternary sediment
- KWOS Windrow Formation (Cretaceous)
- ODCR Decorah Shale (Ordovician)

Sand and Gravel Resources

Sand and gravel deposits are classified as primary and secondary deposits according to their gravel content, thickness, and the thickness of overlying sediments. A tertiary classification is used for deposits of significantly poorer quality. In addition to sufficient thickness and gravel content, and minimum of cover, a relatively wide range of size from sand to gravel is desirable in a deposit, because different size mixtures are required for different uses. The demand for gravel relative to the supply is generally higher than for sand, so gravel-rich deposits are more valuable than sand-rich deposits.

Areas shown by pattern are considered to have potential for aggregate resources. Pockets of gravel are also present in unpatterned areas, but such deposits tend to be small, thin, and covered. However, many small pits are opened in areas not mapped as resources, as shown on the map. Much of this gravel is used locally, for example, on the same farm from which it is extracted.

Primary resource—Deposits generally have (1) more than 35 weight percent gravel (material larger than 2 millimeters in diameter), (2) sand and gravel deposits more than 20 feet thick and (3) less than 10 feet of overburden. The resource is limited in areas having a high water table.

Low water table—Water table is generally 20 or more feet below surface of resource.

High water table—Water table is less than 20 feet below surface of resource.

Secondary resource—These deposits are (1) less than 35 percent gravel, (2) less than 20 feet thick, or (3) have more than 10 feet of cover. A high water table may also be a limiting factor but is not separately mapped. Some areas mapped as secondary contain pockets of primary resource, but these generally cannot be mapped with confidence.

Tertiary resource—Both the quantity and quality of gravel are severely limited. Tertiary resources can be used for common fill and for applications that require mostly sand. In places, gravel is abundant enough to be mined for applications that do not require high resistance to abrasion.

Sand and gravel pit—Symbol represents active and inactive pits.

TESTS FOR QUALITY OF AGGREGATE

LAR (Los Angeles Rattler test)—This is a standard method of testing the resistance of aggregate to abrasion, in which coarse crushed rock is rotated in a steel cylinder for a specific period of time. The percentage of fine material that is abraded from the aggregate in relation to the amount of aggregate originally placed in the cylinder is the LAR loss percentage.

Magnesium sulfate test—This test requires repeated cycles of immersion of aggregate in a solution of $MgSO_4$ and drying, and causes some rock to weaken and be lost upon repeated expansion of salt crystals in pore spaces. The results are expressed as a percentage of fine material lost, and therefore the sounder the aggregate, the lower the values. The test is used to simulate and predict the effects of freezing and thawing.

The $MgSO_4$ values typically are larger, indicating "less sound material," in aggregate having large percentages of bedding features and high clay content (Harvey and others, 1974). In addition, nearly pure limestone or dolostone tends to be more sound than limy dolostone or dolomitic limestone.

Insoluble residue is the material that remains after solution of the rock in hydrochloric acid. Residues typically consist of silica (sand, silt, and chert), shale, iron oxide, and organic material, which are deleterious for many aggregate uses.

Spall material is a term used by the Minnesota Department of Transportation for rock particles, such as shale, which expand when wet, causing a popout or spall in hardened concrete. The percentage of shale in a sample is determined both from sand-size particles, which pass through the number 4 sieve, and from the gravel, which is retained on the number 4 sieve. Openings in this sieve are 0.187 inch (4.75 mm) in diameter. The percentage of iron oxide and unsound chert, however, are determined from the gravel only. Sand-size particles of shale float when placed in a heavy liquid (specific gravity of 1.95), and are thereby separated from particles of sand, which sink. The amount and type of spall material in the gravel are determined by visual examination of each pebble in the sample.

Table 1. Summary of analytical test results for crushed rock from carbonate rock units in Goodhue County, Minnesota.

[Data from Minnesota Department of Transportation. Avg, average; no, number of separate analyses on which average values are based; range, minimum and maximum values obtained; n.a., not available.]

Geologic Unit	Los Angeles[1] Rattler Test		Insoluble[2] Residue		Magnesium[3] Sulfate	
	Avg (no)	Range	Avg (no)	Range	Avg(no)	Range
Galena Group	34.0(6)	30.3–40.0	13.0(18)	9.3–15.0	n.a.	n.a.
Shakopee Formation	40.1(5)	38.7–42.7	3.7(9)	2.7–4.4	18.7 (15)	10.7–24.1
Oneota Dolomite	35.6 (4)	33.6–37.9	2.9(24)	2.0–3.7	14.5 (15)	4.9-27.2

[1]Test results expressed as percentage of loss.
[2]Test results expressed as percentage of insoluble material.
[3]Test results expressed as a percentage of fine material lost.

Table 2. Summary of pertinent information on sand and gravel for aggregate from pits in Goodhue County, Minnesota.

[Data from Minnesota Department of Transportation pit sheets; see text for discussion. See Plate 3 for additional information on geologic units. Abbreviations: ft, feet; avg, average; no, number; %, percent.]

Geologic Units	Number of		Overburden Thickness (ft)		Borings		Gravel Content All Pits(%)	
	Pits	Borings	Avg	Range	Depth(ft) Avg	To Water Table (no)	Avg	Pit Range
PRIMARY RESOURCES								
Grey Cloud & Langdon terrace deposits (Qgct & Qlt)	7	198	3.1	1.0–5.5	24.1	5	63.10	48.6–81.9
Miss. valley train (Qmo)	2	13	1.4	1.3–1.5	22.4	0	38.70	36.6–40.8
New Ulm Fm. outwash (Qdo)[1]	8	405	2.4	1.3–3.1	19.1	56	39.40	31.5–44.7
SECONDARY RESOURCES								
New Ulm Fm. outwash (Qdo)[2]	6	257	2.7	2.3–3.1	17.2	45	32.10	28.3–44.0
Pierce Fm. outwash (Qpko)	5	70	2.2	1.9–3.3	14.2	0	36.90	17.2–66.7
River Falls Fm. outwash (Qpso)[3] and Pierce Fm. glaciofluvial deposits (Qpsg)	10	115	2.6	0.8–5.3	17.0	3	34.00	17.4–58.0
TERTIARY RESOURCES								
Michigan alluvium (Qmal)	2	13	4.0	1.8–6.3	21.2	0	25.70	16.9–34.6

[1]Outwash within Prairie Creek and Cannon River drainages.
[2]Outwash along the North Fork Zumbro River.
[3]No pit data were available for unit Qpso; it is included here owing to its similarity to unit Qpsg.

Table 3. Summary of Los Angeles Rattler and spall-content test results of sand and gravel for aggregate from pits in Goodhue County, Minnesota.

[Data from Minnesota Department of Transportation pit sheets, which provide average values by pit ; see text for discussion. See Plate 3 for additional information on geologic units. No, number.]

Geologic Units	Data Sources (no)		Los Angeles Rattler Tests[1] Size A (3/8–1-1/2 inch)		Size B (3/8–3/4 inch)		Spall Material[2] Shale in		Iron
	Pits	Borings	Mean	Range	Mean	Range	Sand	Gravel	Oxide
PRIMARY RESOURCES									
Grey Cloud & Langdon terrace deposits (Qgct & Qlt)	5	152	24.6	20.0–26.7	25	21.0–26.7	0.09	0.04	0.07
Miss. valley train (Qmo)	1	6	22.3	22.3	28.4	28.4	0.3	0	0
New Ulm Fm. outwash (Qdo)[3]	6	342	27.9	27.4–29.2	26.4	25.4–27.4	0.75	0.38	0.51
SECONDARY RESOURCES									
New Ulm Fm. outwash (Qdo)[4]	5	234	30.7	28.0–33.7	29.1	28.0–33.5	0.14	0.14	1.68
Pierce Fm. outwash (Qpko)	3	40	25.1	25.1	25.8	25.8	0.1	0	5.45
River Falls Fm. outwash (Qpso)[5] and Pierce Fm. glaciofluvial deposits (Qpsg)	4	50	27.6	24.6–30.7	27.4	26.0–29.5	Trace	Trace	4
TERTIARY RESOURCES									
Michigan alluvium (Qmal)	1	21	49.3	49.3	47.9	47.9	0	Trace	0.8

[1]Test results expressed as percentage of loss.
[2]Test results expressed as percentage of spall material.
[3]Outwash within Prairie Creek and Cannon River drainages.
[4]Outwash along the North Fork Zumbro River.
[5]No pit data were available for unit Qpso; it is included here owing to its similarity to unit Qpsg.

Economic Ranking of Quaternary Resources

Primary Resources

Grey Cloud and Langdon terrace deposits (units Qgct and Qlt on Plate 3): all the pits with test results are in Grey Cloud terrace, but both deposits are similar and combined here. This resource is frequently used by gravel pit operators, in part because it is in and near the Mississippi River valley, close to Red Wing and Highway 61, and because of the high quality of the deposits. The proportion of gravel (Table 2) is the highest of the sand and gravel units in the county, and LAR and spall values are among the lowest. High water table was not a problem in the reported pits, but it could be in lower lying parts of this deposit, most of which have not been mined. Urban development covers much of the deposit, especially in the Red Wing area. The largest remaining undeveloped areas are Prairie Island and eastern Florence Township.

The ***Mississippi valley train*** (unit Qmo on Plate 3) is exposed at the surface in only a small area, but it underlies most of the Mississippi terrace deposits. Its proportion of gravel is within the range for a primary source of aggregate, and the LAR and spall values are low (Table 2, 3). Most of the material was washed from glacier margins in the Minneapolis–St. Paul area, and stream transport has broken down some of the weaker fragments. The largest component of the gravel came from the Superior lobe of the ice sheet, so it is rich in hard igneous and metamorphic rocks. Some limestone and dolostone fragments are present, and a very small amount of shale, but both are fewer than in Des Moines lobe outwash. Iron-oxide grains are not a problem in either this unit or in Mississippi terrace deposits.

Des Moines–lobe outwash is widespread and contains many gravel pits despite its marginal quality. The outwash is here divided into two subunits: that in the Prairie Creek and Cannon River drainages is the poorest of the primary resource, and that along the North Fork Zumbro River is the best of the secondary resource. The deposit is thicker than 20 feet in most places where it is mined, but the shallow water table is a problem in places.

Des Moines outwash within the Prairie Creek and Cannon River drainages (part of unit Qdo on Plate 3) has an average gravel content that is in the range for a primary resource, and the spall values are generally acceptable for concrete aggregate. Shale values are somewhat higher than for Des Moines outwash along the North Fork Zumbro River, but the iron oxide content is much lower.

Secondary Resources

Des Moines outwash along the North Fork Zumbro River (part of unit Qdo on Plate 3) has lower average gravel content and higher average spall and LAR values than that along Prairie Creek and Cannon River. A high water table is also a common limitation. Nevertheless, this unit is heavily mined.

Outwash of the Pierce Formation (unit Qpko on Plate 3) forms a terrace along the Zumbro River that is higher than that formed by Des Moines outwash discussed above. The water table is low. The deposit is mostly too thin to be a primary resource. Gravel content varies. Iron-oxide content is high, which is generally true of older deposits.

The secondary resource of glaciofluvial deposits includes ***outwash of the River Falls Formation and glaciofluvial deposits of the Pierce Formation*** (units Qpso and Qpsg on Plate 3). Some deposits would rank as a primary resource, but the average test values do not place it there. Because of the upland position of the resource, the water table generally does not occur within it. The thickness of overburden is variable, but it generally is not thick enough to preclude mining. However, many unmined delineations of this unit are covered by loess (Plate 3), and the overburden is correspondingly greater.

These deposits were weathered during one or more warm interglacial periods. Many rock particles are weakened by weathering, and the content of spall material tends to be high, almost all of it iron oxide. LAR values are moderately high but acceptable. The deeper parts of some of these deposits are significantly less weathered, but most of them are not thick enough to have much unweathered material.

Tertiary Resources

Alluvium of the Michigan Subepisode (unit Qmal on Plate 3) is mostly sand and has a variable amount of gravel. It forms terraces in places above the modern floodplains but also fills the valleys under the modern alluvium. In most places, thickness is not a limiting factor. Gravel content is low on average and quite variable from place to place. Only one pit sheet in this unit shows LAR and spall values (Table 3): the LAR values are too high for use in highway pavement, but the spall values are acceptable. At this site, most of the gravel is clasts of local carbonate rock, weathered from the walls of the valley. Lower LAR values might be expected from pits in this unit in the Red Wing area, where glacially derived pebbles are more common, but no data are available. The parts of this alluvium overlain by loess were not mapped as a resource, because the additional overburden on an already marginal deposit probably precludes mining.

Modern ***alluvium*** (unit Qhal on Plate 3) is not mapped as a resource as it contains little or no gravel itself. However, it overlies gravel-rich deposits in places. Some gravel pits could be expanded into areas of alluvium, although a high water table and occasional flooding would be expected. In the upper reaches of many streams, the layer of alluvium is thin enough to be stripped, but in the Mississippi valley, and the lower parts of its tributaries, the alluvium is too thick for this to be feasible.

INTRODUCTION

Goodhue County is endowed with geologic resources useful to its residents. The demand for particular resources has changed over time as needs and the technology to satisfy them have changed. Historically, the geologic formations of the county provided stone for building, lime for mortar, and clay for pottery, brick, and tile. Currently, crushed rock, sand, and gravel are extracted, mostly for building roads.

The map shows the location of both inactive and active pits and quarries. It is common for quarries to cease operations, lie dormant for some time, and then go back into operation as demand and prices change.

This map is based solely on geologic criteria. Urban development, land-use restrictions, and economic considerations are also important factors in determining the feasibility of mining natural resources. These factors are subject to abrupt changes and therefore are not considered here. The digital version of this map can be compared with these other themes in a Geographic Information System (GIS).

BEDROCK RESOURCES

Carbonate Rock Resources

Carbonate bedrock is quarried in the county and crushed for use as aggregate, riprap, and agricultural lime. The Minnesota Department of Transportation has compiled a limited body of data regarding the suitability of these carbonate rocks in concrete and bituminous pavement. The samples that were tested can be related to specific formations, but not always to specific members of a formation. Consequently, the test results can only be used as a general guide, and they may not apply to the entire thickness of a formation, or over its entire subcrop (Table 1).

Limited tests suggest that rock of the Galena Group (or those parts of it that have been tested) produces aggregate suitable for use in concrete, but its insoluble residue content is too high for bituminous pavement. The Stewartville Formation of the Galena is not present in Goodhue County, and the Cummingsville Formation has abundant interbedded shale, especially in its lower half, making it less desirable as a resource. The Prosser Limestone is the only part of the Galena Group likely to provide a significant resource.

Tests of samples from the Shakopee Formation indicate LAR abrasion loss of 38.7–42.7 percent with a mean value of 40.1 percent. A value of 40 percent or less is required for use in concrete or bituminous paving. Magnesium sulfate tests yielded values of 10–24 percent loss and a mean of 18.7 percent. Use in concrete paving requires less than 15 percent loss, and use in bituminous paving requires less than 20 percent loss. All tests for insoluble residue show values well within the requirement of less than 10 percent for bituminous paving. These limited data suggest material from the Shakopee Formation will commonly fail to meet paving standards.

Samples from the Oneota Formation indicate some material from the formation meets the requirements for use in concrete and bituminous paving, but some samples fail the magnesium sulfate requirements.

There are no available data on the suitability of the Platteville Formation in paving mixtures.

The map shows the location of both active and inactive quarries. Only three counties statewide have more active quarries than Goodhue County, and there are almost 100 inactive quarries (Nelson and others, 1990). Existing quarries are generally located near an eroded edge of a resource because of the advantages associated with mining horizontally into the rock. More site-specific studies within these areas would be required to locate resources more accurately. The limestone of the Platteville Formation is not mapped as a resource because it is generally too thin to be quarried economically.

Sandstone Resources

The St. Peter Sandstone is mined for fill. The Jordan Sandstone is also a likely source for this use. There are historic accounts of white sand from the Red Wing area being used for the manufacture of glass (Hancock, 1888).

Historic Resources

Dimension Stone

The bluffs of Red Wing supplied dimension stone blocks for foundations, bridges, and other uses from the middle of the nineteenth century until at least 1916 (Eide, 1941). Most of the quarries were located at Barn Bluff or Sorins Bluff, or at other locations very close to downtown Red Wing. The quarries produced stone from the Shakopee and Oneota Formations. Proximity to the river made shipping by barge attractive. Much stone was used locally, but it was also shipped and used in projects like the stone arch bridge at Saint Anthony Falls in Minneapolis (Eide, 1941). Quarry locations in the city eventually worked against the industry when residents became annoyed with the noise and flying debris produced by blasting.

Clay

Possibly the most widely known of Goodhue County's natural resources is the clay that was mined there, due to the reputation of the stoneware, dinnerware, and other pottery manufactured from it. Accounts of the history of the industry from the Goodhue County Historical Society indicate that the clay was used for pottery at least as early as 1862 (Red Wing Collectors Society, 1996). By the late 1800s, the clay was mined in commercial quantities and was later used to manufacture sewer pipe as well as stoneware (Fig. 1).

The clay and associated sediments have been assigned to the Ostrander Member of the Cretaceous Windrow Formation (Andrews, 1958). F.W. Sardeson (1889) suggested that the clays were an example of glacial transport of large bedrock blocks en masse. This phenomenon has been documented elsewhere in the state since that time (for example, Knaeble, 1996). It is an attractive theory because the clay occurs in "lenses or tabular bodies as much as a few feet thick and several tens of acres in areal extent that are intercalated with ferruginous sands" (Austin, 1963). Only the clay bodies that have been mined have been shown to extend over such wide areas.

There is very little left of these deposits today. The industry declined because the known deposits were mined out, and suitable replacements could not be found. By the early 1930s one large sewer-pipe factory closed for this reason. Previously, the clay was mined by men with hand shovels so that thin sand layers within the clay could be kept separate from the clay (Johnson, 1986) (Fig. 1). Later, powered equipment was used for excavating because the remaining clay was of insufficient quality for pottery, and clay for sewer pipe did not require hand work. The pottery operation continued for some time by importing clay from Ohio and elsewhere. Sewer pipe was manufactured until 1972.

A previous investigation (Austin, 1963) mapped Cretaceous strata in an area approaching 75 square miles in east-central and northeastern Goodhue County. Since that time, a subsurface data base of well records and downhole geophysical logs has been created as an aid to bedrock mapping. This information shows that the deposits are too discontinuous to be represented as a mappable unit.

The clay pits shown on the resource map all relate to this industry, with the exception of the pit northeast of Wanamingo that mined Decorah Shale. One of the clay pits northeast of Goodhue, known as the Hinsch pit, mined Pleistocene clay.

Lime

Before the invention of portland cement, natural hydraulic cement was produced by burning limestone. A limestone with the proper amounts of calcium carbonate and clay was required, and the bluffs near Red Wing yielded a well-suited limestone. The lime manufacturing industry flourished in this area from the mid 1800s to about 1908 (Blondell, 1940). Its product was known throughout the northwest until the advent of portland cement ended demand for it (Blondell, 1940).

QUATERNARY RESOURCES

The major Quaternary resource in Goodhue County is sand and gravel, which is used mostly for road construction and maintenance but also in general construction. Contractors prefer to obtain gravel close to the site of use, because the cost of hauling is a large part of the total cost. Thus, gravel is mined in many parts of the county, rather than in just a few of the very best deposits. Some sand and gravel deposits are limited by high water table. In Goodhue County, probably more gravel exists below the water table than above. Although it is possible to extract gravel below the water table, it requires special equipment, or the deposit must be dewatered.

Sand and gravel resources are further distinguished by geologic origin, because the quality of the deposit is influenced by its origin. For example, gravel derived from the Des Moines lobe contains at least a little shale, whereas gravel from other sources contains very little or no shale. The content of iron-oxide clasts tends to be higher in the Des Moines lobe deposits as well, though the highest iron-oxide values are found in older deposits and are probably due to weathering. Los Angeles Rattler (LAR) values (Table 3) are also correlated to geologic origin. Gravel from the Des Moines lobe has relatively high values because of its content of soft shale and carbonate fragments. The highest LAR values are from the alluvium of the last glaciation (alluvium of the Michigan Subepisode; unit Qmal on Plate 3), which includes much local limestone derived from the valley walls.

Sources of Data

The numerical data shown in Tables 2 and 3 were summarized from pit sheets of the Minnesota Department of Transportation. Pit in this context means the area tested for aggregate, regardless if there is an actual pit there. The pit sheets report the results of soil borings and sampling undertaken by Minnesota Department of Transportation in areas where state highway projects are planned. The distribution of soil borings and other data is not optimal for a statistical study of the various gravel deposits in the county. The information was collected as needed, where needed, to support anticipated construction projects. Test results that are consistently similar from many pits within the same unit are probably representative. A large variation among pits is a signal that the average values may not be valid. In short, although these numbers can be taken as a guide to aggregate quality, on-site investigation still has to be done to ensure that the deposit meets specifications.

All active and many inactive pits were visited, and the deposits described in a general way. The depth of leaching and other signs of weathering were noted. Texture and rock type of samples were also determined.

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