UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
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MINERAL ENDOWMENT

INTRODUCTION

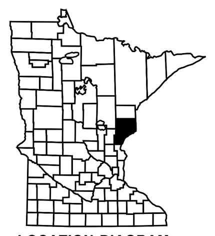
The two maps on this plate show the distribution of historic test pits and showings of native copper (all subeconomic) and established and potential sources of construction aggregate and dimension stone. The construction aggregate is classified into bedrock aggregate (crushed rock) and natural aggregate (gravel and sand), and the natural aggregate is further classified into three classes based on quantity and quality criteria that affect the potential viability of the deposits as economic resources.

The terms ***mineral endowment***, ***geological endowment***, or ***endowment*** refer to the geologic materials that have intrinsic economic value and thus, potentially, could be mined and marketed. A ***mineral resource*** is a narrower or more restricted portion of the geological endowment; it is "a concentration or occurrence of material of intrinsic economic interest in or on the Earth's crust (a deposit) in such form and quantity that there are reasonable prospects for eventual economic extraction. . . . Portions of a deposit that do not have reasonable prospects for eventual economic extraction must not be included in a mineral resource" (Resources and Reserves Committee, 1999). Among the factors that may remove some portion of an endowment from consideration as a resource are zoning restrictions, landownership considerations, prohibitive taxation, competing surface uses, and environmental considerations, in addition to the supply-demand price fluctuations of the commodity marketplace. The authors of this plate did not take into account these socioeconomic factors, and therefore the map portrays the mineral endowment of Pine County, not the mineral resources.

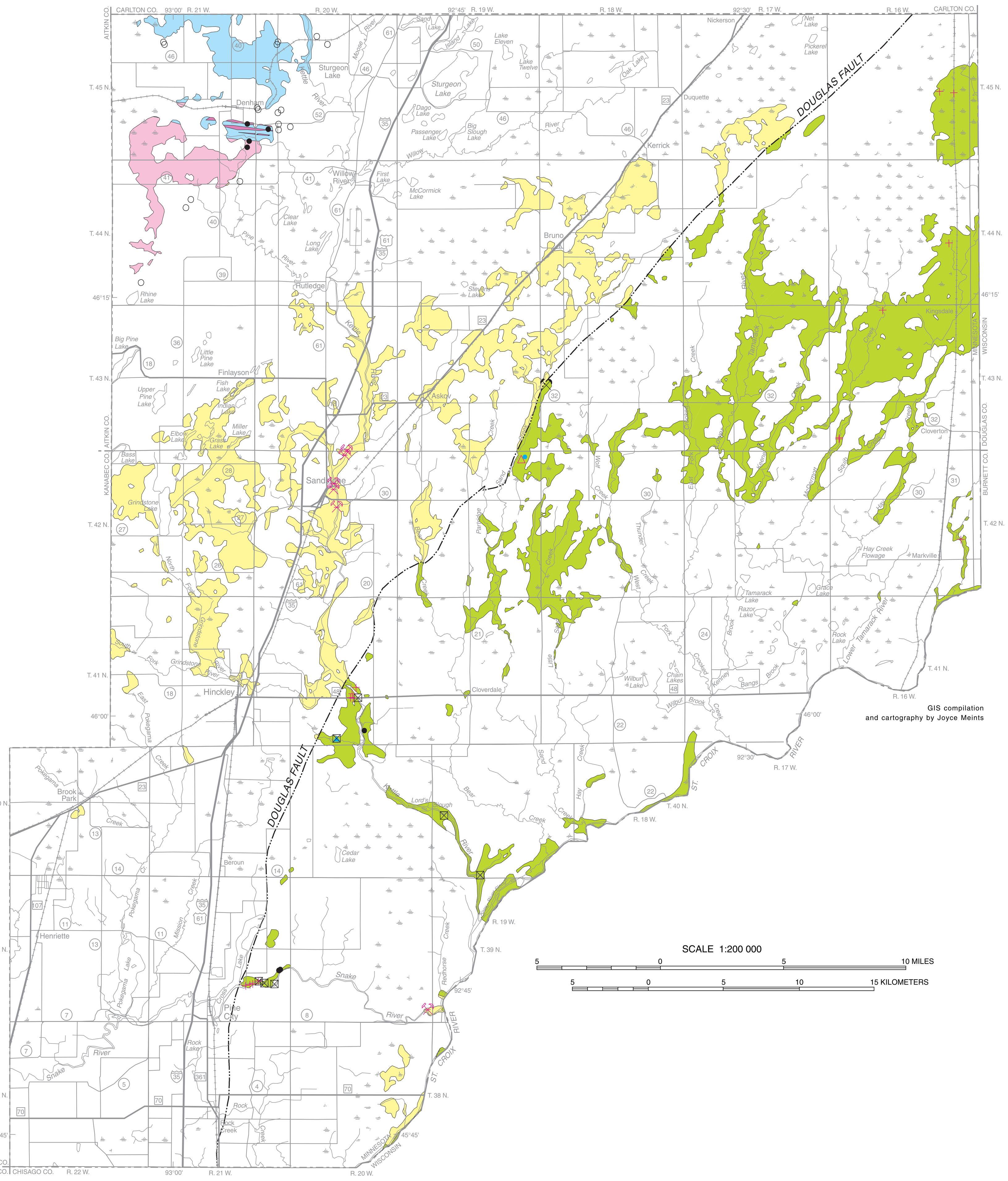
The ***geological endowment*** of a mineral commodity can be defined and quantified on observable physical and compositional attributes of the deposit, such a deposit thickness, overburden thickness, horizontal dimensions, measures of crushing strength, particle-size distribution, etc. A mineral resource must possess favorable attributes of this type, but in addition it must be relatively unencumbered by socioeconomic factors that would remove it from consideration as the basis of a business enterprise.

REFERENCE

Resources and Reserves Committee, 1999, A guide for reporting exploration information, mineral resources, and mineral reserves: Littleton, Colo., report submitted to the Board of Directors, Society for Mining, Metallurgy and Exploration, 17 p.



LOCATION DIAGRAM



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
1983 North American Datum

Bedrock Endowment

By

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2001

BEDROCK AGGREGATE (CRUSHED ROCK)

Only one quarry in Pine County is presently in operation; it is located east of the City of Askov in Fleming Township (T. 43 N., R. 18 W.). Basalt extracted from the quarry is crushed to produce traprock aggregate materials, which are used mainly for resurfacing local township and private gravel roads. To date, the material from this quarry has not been tested by the Minnesota Department of Transportation for suitability in bituminous or concrete paving. Other near-surface or surface exposures of basalt may also contain material suited for crushed-rock aggregate production. As a general rule, outcrops of basalt that are located away from the Douglas fault are more likely to contain fresh, hard crystalline bedrock that will meet the testing criteria for construction of paved roads.

The Hinckley and Fond du Lac sandstones (see Plate 2) are not suitable for use as road aggregate, as they are relatively soft and friable in comparison to crystalline rocks in Pine County. Given its uniform fine-grained sandy texture, the Hinckley Sandstone could potentially be crushed to form industrial quartz sand similar to that currently being produced from the Jordan Sandstone in southeastern Minnesota, but the material would need to be tested to determine suitability for this purpose.

The northwest corner of Pine County contains numerous surface exposures of crystalline bedrock, including schist and gneiss (Plate 2). These rocks have not been tested for aggregate suitability. However, they are similar in composition and texture to bedrock presently quarried in other parts of the state for this purpose. In particular, the McGrath Gneiss is similar to rocks quarried near St. Cloud, Granite Falls, and Ortonville for high-quality aggregate used for bituminous and concrete road surfaces, among other uses. The schistose rocks located to the north of the McGrath Gneiss may provide aggregate suitable for use in pavement.

COPPER SHOWINGS

Several copper exploration shafts have been reported in Pine County—for example, Upham (1888) and Martin (1985 and references therein). The shafts were constructed prior to 1900. They were reportedly located along the banks of the Snake River downstream from Cross Lake and Pine City, the banks of the Kettle River east and southeast of the City of Hinckley, and along the Kettle and St. Croix Rivers in and near St. Croix State Park. The exploration shafts followed showings of native copper in veins and flow features within the volcanic rocks of the Chengwatana Volcanic Group (Plate 2). Some shafts reportedly were several hundred feet in depth. Although copper was apparently found in sufficient quantity to spur exploration, none of the reports indicate that any copper was actually shipped as ore. The copper exploration in Pine County and adjacent areas of Wisconsin was spurred by the discovery of native copper deposits of large tonnage in the Upper Peninsula of Michigan and the similarity of those rocks to the volcanic rocks in Pine County.

The locations of test shafts shown on the bedrock endowment map were gleaned from historical reports and from observation of extant shafts. Effort was made to locate all of the reported test shafts, with limited success. The map also shows locations where finely disseminated copper was noted during field work completed as part of the study, locations where basalt has been pervasively altered to epidote, and locations where float copper has been found by the author during field mapping.

DIMENSION STONE

Material from the Hinckley Sandstone was formerly quarried for use as dimension stone. Dimension stone is rock that is fabricated into tiles, slabs, or blocks. The quarries in Pine County operated from 1885 until the late 1930s (information from the Sandstone Historical Society); they are located in what is now Robinson Park in the City of Sandstone, and in Banning State Park. The sandstone was fashioned into building materials that included flagstone, curbing, and blocks for buildings and bridge footings.

Material from the McGrath Gneiss, and possibly the marble unit within the Denham Formation, may have value as dimension (or building) stone (refer to Plates 2 and 3 for additional information on rock units). Market demand, accessibility, and the suitability of stone for quarrying determine the feasibility of quarrying rock. Potential dimension stone must (1) be of a desired color and/or texture, (2) be relatively free of fractures, and (3) pass a series of physical and chemical tests for strength and durability. Cores from drill holes that have penetrated the marble unit immediately north of the Denham Formation outcrops indicate that the marble persists several hundred feet in depth. Although the marble is generally tan where it is exposed at the land surface, in the subsurface it is generally gray to (in places) pale pink, green, or white.

MAP UNITS AND SYMBOLS

See accompanying text for additional information on the materials listed below.

Areas where depth to bedrock is less than 25 feet.

Sandstone and siltstone—Includes Paleozoic rocks, Hinckley Sandstone, and Fond du Lac Formation.

Basalt.

Dolomitic marble.

Schistose rocks—Includes metamorphosed graywacke, basalt, and arkose.

McGrath Gneiss.

Quarries.

Inactive dimension-stone quarry.

Active quarry for production of crushed rock.

Copper showings.

Float of epidote-altered basalt containing disseminated copper.

Outcrop of basalt showing disseminated copper.

Native copper in prehnite vein.

Basalt with pervasive epidote alteration.

Uranium exploration drill hole.

Test pits and shafts.

Test pit observed by Minnesota Geological Survey field geologist—The four test pits shown in the far northwestern corner of the county were observed during the course of field work. Two are located in the McGrath Gneiss and may have been excavated during early uranium exploration activities. The other two are located on and adjacent to a narrow northwest-trending diabase dike that contains substantial pyrrhotite. Because pyrrhotite is magnetic, it is assumed that these excavations were made as a follow-up to early dip-needle magnetic surveys. Test pits in southern Pine County were excavated as part of copper exploration efforts prior to 1900; these include water-filled shafts of unknown depth.

Shaft reported but location could not be verified during field work for this atlas.

REFERENCES CITED

Martin, D.P., 1985, A compilation of ore mineral occurrences, drill core, and testpits in the State of Minnesota: Minnesota Department of Natural Resources, Division of Minerals Report 231, 266 p.

Upham, Warren, 1888, Copper-bearing trap, *a section in* Upham, Warren, Geology of Pine County: Geological and Natural History Survey of Minnesota Final Report, v. 2, p. 632–637.

A Selection of Minnesota Department of Transportation Specifications for Aggregate

AGGREGATE CLASSES

Class A—"crushed quarry or mine trap rock (basalt, diabase, gabbro or other related igneous rock types), quartzite, or granite." *These are rocks that are more uniform throughout a quarry and generally have fewer deleterious qualities.* ***Note: No class A aggregate has been identified in Pine County, although trap rock (basalt) and granitic rock (McGrath Gneiss) are present, and a deposit of Class A material could potentially be developed.***

Class B—"all other crushed quarry or mine rock: i.e., carbonates, rhyolite, schist." *These are rocks that are not as uniform within quarries and have some deleterious qualities. In the case of carbonate rock, it is void space in the rocks that absorbs moisture, which freezes and causes cracking of pavement.* ***Note: No class B aggregate has been identified in Pine County.***

Class C—*natural or partly crushed natural gravel;* ***class D***—*100 percent crushed natural gravel;* ***class E***—*mixtures of two or more classes of aggregate; and* ***class R***—*recycled concrete.*

GRADED AGGREGATE USED IN ASPHALT MIXTURES

Quality tests include crushed rock, natural gravel, and mixtures.

Los Angeles rattler loss in the coarse fraction [material retained on the 4.75-millimeter (#4) sieve (gravel sized or coarser)] shall not exceed 40 percent for any individual source used in the mix.

Magnesium sulfate loss in the coarse fraction [material retained on the 4.75-millimeter (#4) sieve (gravel sized or coarser)] shall not exceed:

a. more than 14 percent on the 19-millimeter (3/4 inch) to 12.5-millimeter (1/2 inch) and larger fractions;
b. more than 18 percent on the 12.5-millimeter (1/2 inch) to 9.5-millimeter (3/8 inch) fraction;
c. more than 18 percent on the 9.5-millimeter (3/8 inch) to 4.75-millimeter (#4 sieve) fraction;
d. more than 18-percent composite loss (applies only if all three size fractions are tested).

Spall materials and lumps

Low volume mixtures—
Total spall in total sample 5.0%

Data From Minn. Dept. of Transportation and Milestone Materials, Onalaska, Wisconsin

Table 1. Average test data for gravel from different surficial geologic units in Pine County.

[-- (leaders), no data available; the columns are numbered for convenience.]

The test data summarized here were obtained on samples from Minnesota Department of Transportation pits. The entire data set is available; contact the Minnesota Department of Transportation for further information. The results of tests are grouped by the geologic interpretation of the units. The unit labels in **column 1** are the same as used on the Surficial Geology map (Plate 4), except that Qglf and Qgls are lumped into one unit, Qgl. In cases where the unit being mined was not at the surface, the units overlying and underlying the producing unit are indicated. **Note that the producing units are shown in boldface type.**

Column 2 shows the average percentage of shale retained on the number 4 screen (gravel). Shale is an undesirable component in aggregate because it is soft and swells when wetted. It can cause a "pop-out" to form in asphalt or concrete—that is, a hole or pit in the surface—as a result of the swelling. All pits tested easily met the Minnesota Department of Transportation shale standard. Shale is not likely to be a problem anywhere in Pine County.

Column 3 shows the average percentage of total spall material determined for the pits where tests were conducted. Spall material includes shale, chert, and iron oxide, and also causes pop-outs. All pits tested met the spall standards and it is unlikely that this will be a problem in the county.

The Los Angeles–rattler (LAR) test (**column 4**) is a measure of resistance of the aggregate to abrasion. Coarse aggregate is tumbled in a steel cylinder for a specified time. The percentage of fine material that is abraded from the aggregate in relation to the amount of coarse aggregate originally placed in the cylinder is the LAR loss percent. The more resistant the aggregate, the lower the LAR values. The LAR standard is 40 and all tests run in Pine County were well within this limit.

The average point score for all pits within a given geologic unit as determined for this assessment is shown in **column 5**. There were a total of 9 points possible for each site. Points were lost if (1) the aggregate at the site did not meet the cutoff value for the standard or (2) no data were available. Individual sites that rated 9 were considered highly desirable and selected areas within the geologic units containing these pits were considered to have primary resource potential. Individual sites that rated 8 or 7 were rated as moderately desirable and selected areas within the geologic units containing these pits were considered to have secondary resource potential. Individual sites that rated 6 or below were considered to have speculative resource potential. More data are required to determine if they fall into the primary or secondary categories, but the geologic units were formed by a process that sorts sand and gravel from finer material.

1	2	3	4	5	6	7	8
Surficial geologic units from Plate 4, showing stratigraphic order	**Shale** (mean percent)	**Spall materials** (total)	**LAR Test** (average)	**Rating** (average, all pits)	**Rating** (range, all pits)	**Pits that have data** (number)	**Comments**
Qgl *over* **Qgs** *over* **Qss**	--	--	--	7.00	7	1	Burial and reworking of Superior-lobe outwash
Qhe *over* **Qssi**	--	1.18	--	7.00	7	1	Stream intersected pre-existing Qssi unit (Plate 4) and deposited it in bar forms now on a terrace
Qhe	0.09	0.22	23.08	6.58	3– 9	19	Best in bar forms on terrace where sand and gravel are thickest. Perched water table in some areas
Qss collapsed	0.09	0.10	18.48	6.50	6–7	2	No comments
Qgm *over* **Qss** collapsed	0.08	0.13	26.50	6.33	5–8	3	Buried by variable thickness of Grantsburg till. Collapse pattern on surficial map on Plate 4 shows probable extent
Qssi	0.07	0.19	21.99	6.30	4–9	43	Easily recognized esker forms; variable texture; lower ratings due to lack of data
Qgs	0.26	0.26	19.45	6.00	4–7	3	Highest shale values in Pine County and sandy in places
Qgl *over* **Qss**	--	0.04	16.73	5.14	2–8	7	Sandy texture and/or depth of burial result in lower rating
Qhs *over* **Qss**	0.06	0.22	21.43	4.73	3–6	11	High water table and less than 20-foot aggregate thickness result in lower rating
Qss *over* **Qssi**	0.05	0.18	17.65	4.67	4–5	3	No sieve data results in lower rating
Qgl *over* **Qss** collapsed	0.07	0.26	19.73	4.60	3–5	5	Lake sediment may have sieved into gravel matrix making it "dirty"
Qss	--	--	22.65	4.00	2–6	5	Sandy
Qsgs	--	--	19.40	4.00	4	1	A single sample with little data results in low rating.
Qgm *over* **Qssi** collapsed	--	--	8.48	3.33	3–4	3	Buried by a variable thickness of Grantsburg till. Collapse pattern on Plate 4 shows probable extent
Qgl *over* **Qsgs**	--	--	--	2.00	2	1	A single sample with little data results in low rating
Qgl *over* **Qssi**	--	--	--	2.00	2	1	A single sample with little data results in low rating

Natural-Aggregate Endowment

By

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2001

INTRODUCTION

The geological endowment of natural aggregate in Pine County consists of sand and gravel deposited by glacial meltwater and postglacial streams. Gravel of good quality is relatively abundant in Pine County. Most of it is nearly free of deleterious materials (for example, shale, limestone, iron oxide, and chert) and has little cover. Drawbacks include a shallow water table in much of the county, deposits that are more sand-rich than desirable, and the thinness of some deposits. Many of the gravel pits in Pine County were tested and developed during the construction of local roads, and Interstate Highway I-35. As aggregate resources become depleted or made inaccessible to the south in the seven-county metropolitan area of Minneapolis and St. Paul, the resources in Pine County may become more important regionally.

In the following discussion frequent reference is made to surficial units on Plate 4. Four- and three-letter codes (for example, Qssi), which are the unit labels on the surficial geology map, are used to designate individual units in the discussion below and in Table 1.

Mapping and Evaluation Criteria

Shown on this map are geologic units in which there is some potential (as judged solely from geological criteria) for the existence of commercially viable gravel and sand deposits. Where available, Minnesota Department of Transportation data that describe aggregate quality and quantity for specific pits were used to identify the geologic units that have the greatest potential. The most highly rated map units have demonstrated aggregate potential as documented by the Department of Transportation reports. Some pits within these areas may be depleted, but the unit is still rated high to indicate its former potential and the extension of the potential to similar units. Geologic units that do not have demonstrated potential as indicated by Minnesota Department of Transportation data are rated lower because they are somewhat speculative, but they may still be of high quality. In all cases, site-specific evaluation is required.

The following geologic map units are described and depicted on Plate 4 (Surficial Geology) and have the best potential for sand and gravel. They are:

1. ***Ice-contact deposits*** of map unit Qssi on Plate 4 (Surficial Geology) and related landforms, including eskers, esker-related collapsed glacial-stream sediment, and kames, as well as fans and bars on stream-eroded terraces (found within map unit Qhe on Plate 4)
2. ***Glacial stream sediment***, which includes map units Qgs and Qss on Plate 4 (Surficial Geology) and ***Holocene stream sediment***, which includes reworked glacial stream sediment (map unit Qhs over map unit Qss). These units typically contain sorted sand and gravel with little silt and clay.
3. ***Shallowly buried sand and gravel deposits*** are more difficult to detect by simply using the surficial distribution of geologic units. They are indicated on the Surficial Geology map (Plate 4) by a collapsed surface expression, or they have been identified where they lie beneath thin lake sediment (map unit Qgl on Plate 4) and windblown sand.
4. Especially good, gravel-rich deposits may be the end-product of two geologic processes that sorted material by size and density. For example, one deposit was interpreted to have begun as an ice-contact stream deposit that formed as water flowed from a wasting glacier (map unit Qssi on Plate 4—Surficial Geology); it was later reworked by water along the vigorous glacial stream course of the St. Croix River (map unit Qhe), and was then left as a terrace—high above the current water table—as the river continued to incise, resulting in the best quality aggregate found in the county.

The geological units are subdivided into one of these subclasses (defined further below) on the basis of the following factors:

1. Sand and gravel thickness;
2. Percentage of material retained on the number 4 sieve (4.76–millimeter mesh) and/or percentage of material retained on the number 10 sieve (2–millimeter mesh);
3. Thickness of the overlying deposit;
4. Depth to water table;
5. Percentage of shale retained on the number 4 sieve (4.76-millimeter pore space);
6. Total spall content; *and*
7. Hardness test (Los Angeles rattler) results.

All deposits in the county meet the shale (less than 0.7 percent by weight), total spall content (less than 1.5 percent by weight), and Los Angeles–rattler (less than 40 percent) standards. The resulting unit classification is therefore based on whether or not the first four criteria could be determined to be satisfied. In some cases a lower ranking resulted from an absence of data.

Mapped Classes of Resource Potential

Potential primary resources (corresponds to the "highly desirable" potential-resource category employed by the Minnesota Department of Natural Resources). These deposits are defined as having (1) a sand and gravel thickness greater than 20 feet; (2) generally less than 5 feet of cover; (3) on average greater than 20 percent of material retained on the number 4 sieve and/or 35 percent of material retained on the number 10 sieve, and (4) a water table at least 20 feet below the surface as interpreted from topographic maps. Probability that sand and gravel deposits exist within these units is high.

Potential secondary resources (corresponds to the "moderately desirable" potential-resource category employed by the Minnesota Department of Natural Resources). These deposits do not meet one or two of the above criteria or there is no data available for one or two of the categories. Sand and gravel thickness (1) may be 10–20 feet; (2) cover may be more than 5 feet; (3) there may be less than 20 percent of material retained on the number 4 sieve or 35 percent on the number 10 sieve, or (4) water may be within 20 feet of the surface. The probability that sand and gravel deposits exist within these units is moderate to high, but the limiting factors (for example, limited thickness or shallow water table) may make them less valuable.

Speculative secondary resources (corresponds to the "less desirable" potential-resource category employed by the Minnesota Department of Natural Resources). These deposits have three or more of the above-mentioned limitations or at least three fields of missing data. The probability of encountering sand and gravel may still be moderate, but owing to the lack of existing pits within these locations they are considered more speculative.

ACKNOWLEDGMENTS

Randy Tilseth, Minnesota Department of Transportation, provided specifications for aggregate issued by the Department.

MAP UNITS AND SYMBOLS

Potential primary resources—This unit includes portions of the stream-eroded terrace deposits along the St. Croix and Kettle Rivers (Qhe), where high-energy streams have concentrated gravel and created bar forms that add to the thickness of the overall stream deposit. In addition, the terraces lie high above the current stream level, and there is no evidence of perched water near the surface. Also included are large eskers and ice marginal fans (Qssi).

Potential secondary resources—Most of the ice-contact deposits fall within this category (Qssi), as do areas of shallowly buried or surficial glacial stream sediment (Qss). These deposits typically have more variability in the sand-to-gravel ratio than those classed as potential primary resources, as well as varying amounts of cover.

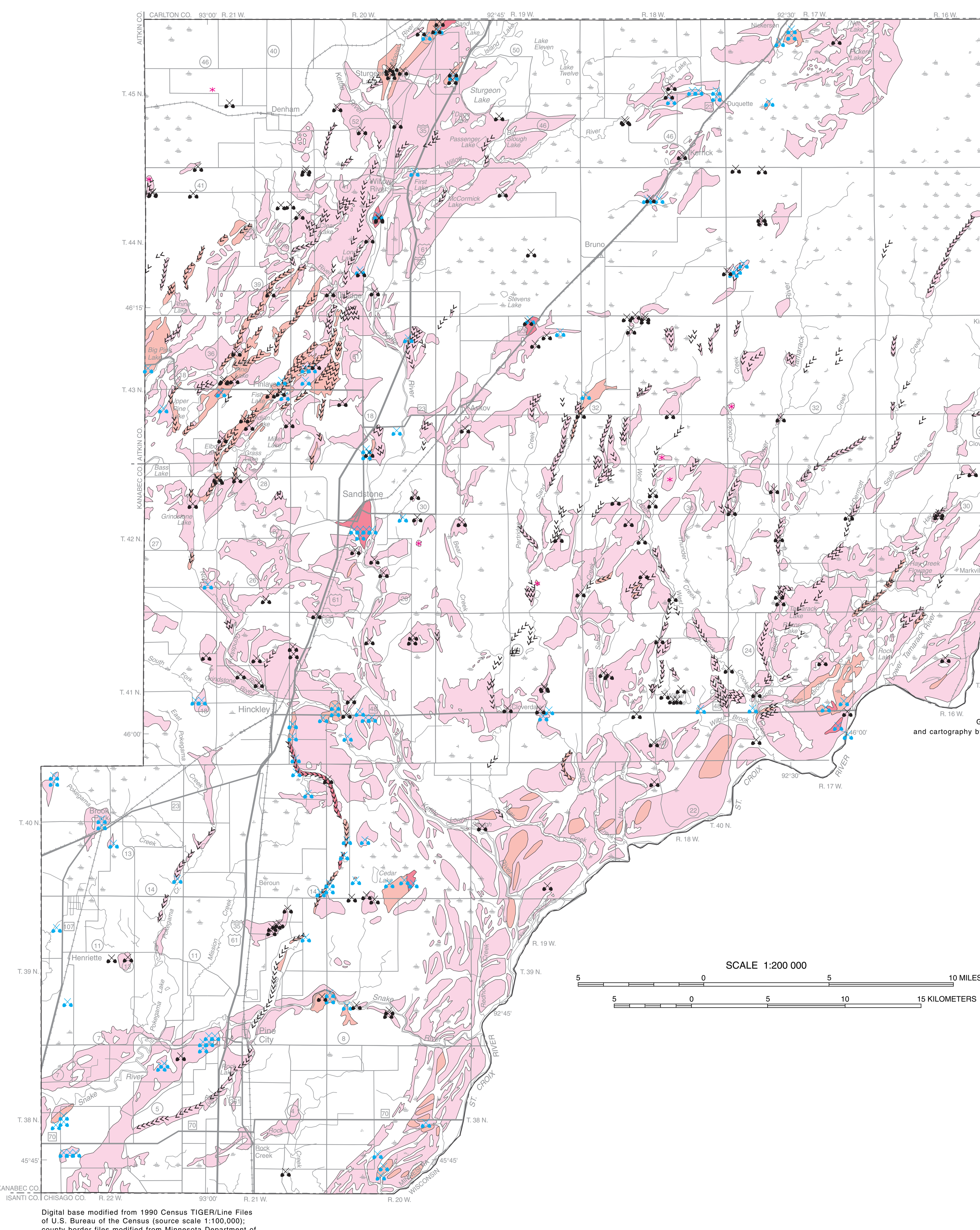
Speculative secondary resources—This unit includes sandy stream sediment (Qsh and Qss), areas of the terrace (Qhe) that have a perched water table or thin deposit, sandy-ice contact deposits (Qssi) or those with high water table or thick cover, or deposits for which there is very little specific information.

Gravel pit or potential area included in the Minnesota Department of Transportation data base—See also Table 1.

Other pit noted during the course of field work or indicated on topographic maps—No tests were run on these pits.

<<<<<<<< **Esker**—Linear ridge composed predominantly of sand and gravel. The fluvial sediment may be covered by as much as ten feet of till. All eskers are interpreted to be of Superior-lobe origin, although thin sediment of the Grantsburg sublobe may in places cover eskers in the southern half of the county.

* **Kame**—Conical hill predominantly composed of sand and gravel.



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
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