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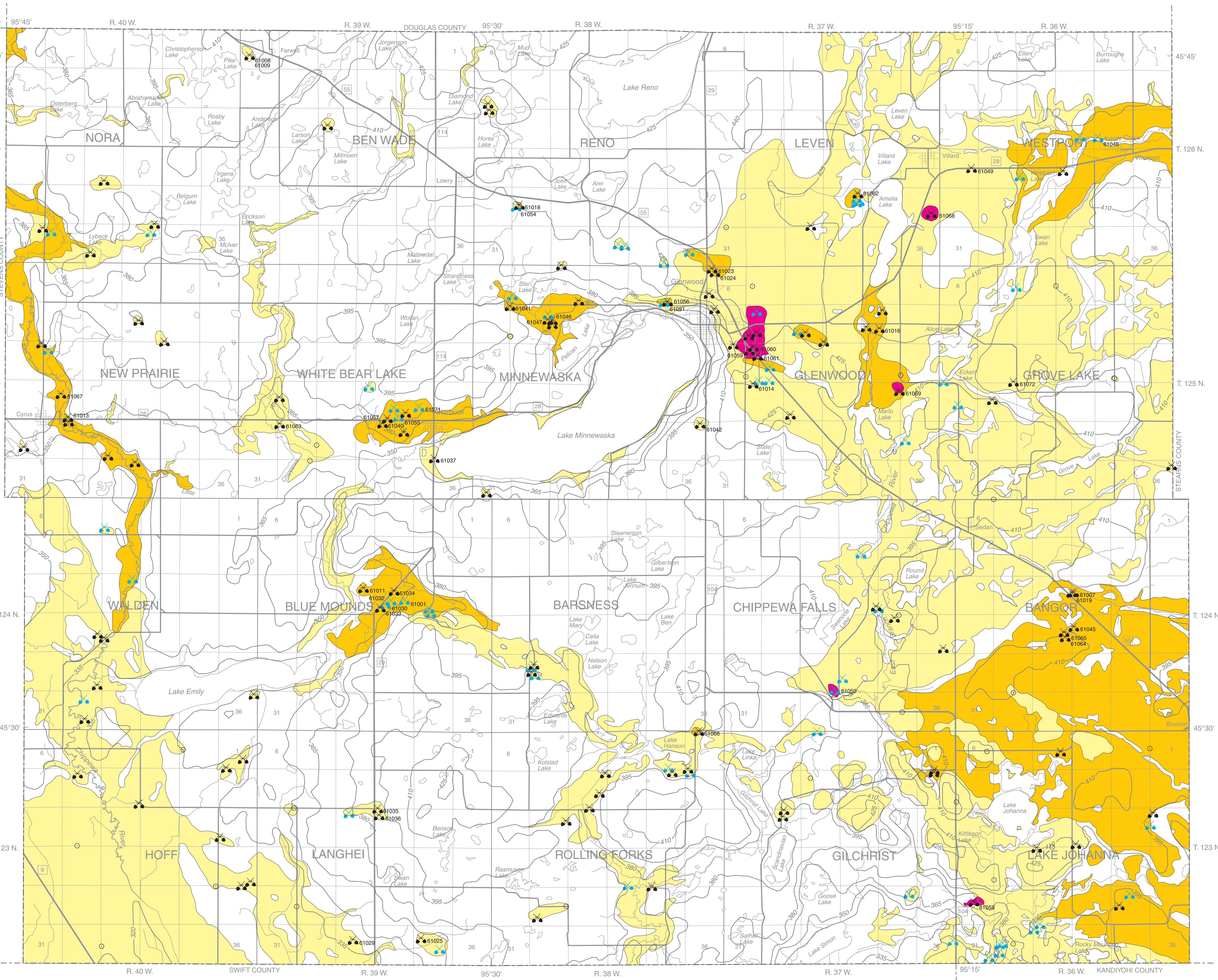
MINERAL ENDOWMENT

By

Alan R. Knaeble, Kenneth L. Harris, and Terrence J. Boerboom

2003



Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

Elevation contours were derived from the U.S. Geological Survey 30-meter Digital Elevation Model (DEM) by the Minnesota Geological Survey.

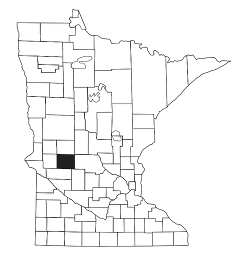
Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum

SCALE 1:100 000

1 0 1 2 3 4 5 MILES

1 0 1 2 3 4 5 6 7 8 KILOMETERS

CONTOUR INTERVAL 15 METERS



LOCATION DIAGRAM

GIS compilation by Joyce Meints
Edited by Lori Robinson

MINERAL ENDOWMENT

INTRODUCTION

This map shows the distribution of natural aggregate (sand and gravel). These deposits are potential sources of construction aggregate and are grouped into three classes, primary, secondary, and tertiary, based on quantity and quality criteria that affect the potential viability of the deposits as economic resources. The map also shows the location of known active and inactive (overgrown) pits and the location of shallow auger boring sites where sand and gravel were encountered. Due to the thick glacial deposits that cover the entire county, a bedrock endowment map was not produced but instead is summarized in the bedrock endowment description.

The terms *mineral* or *geologic endowment* and *mineral resource* refer to the geologic materials that have intrinsic economic value and thus, potentially, could be mined and marketed. The geologic endowment of a mineral commodity can be defined and quantified on observable physical and compositional attributes of the deposit, such as deposit thickness, overburden thickness, horizontal dimensions, measures of crushing strength, and particle-size distribution. A mineral resource is a narrower or more restricted portion of a geologic endowment; it is an occurrence of geologic material of economic interest in such form and quantity that reasonable prospects for eventual economic extraction exist. If a part of the deposit does not have reasonable prospects for eventual economic extraction it cannot be included as 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, land ownership considerations, prohibitive taxation, competing surface uses, and environmental considerations, in addition to the supply–demand–price fluctuations of the commodity marketplace. Therefore a mineral resource must possess favorable attributes and also be relatively unencumbered by socioeconomic factors that would remove it from consideration as the basis of a business enterprise. The authors of this plate did not take into account these socioeconomic factors, and therefore the map portrays the mineral endowment of Pope County, not the mineral resources.

DESCRIPTION OF MAP UNITS AND SYMBOLS

Primary potential sources—These units are defined as having a sand and gravel thickness greater than 20 feet; generally less than 5 feet of overburden (materials other than sand and gravel); on average greater than 35 percent of material retained on the number 10 sieve; a water table at least 20 feet below the ground surface; and quality testing averages that meet the Minnesota Department of Transportation standards in coarse aggregate for concrete used in highway construction, by weight percent of total sample, which are: shale, 0.7 percent; soft iron oxide particles, 0.3 percent; total spall materials[2] (shale and iron oxide, plus unsound chert, coal, and clayey limestone), no more than 1.5 percent. Probability that sand and gravel deposits exist within these units is high. Corresponds to the "highly desirable" potential-resource category employed by the Minnesota Department of Natural Resources.

Secondary potential sources—These deposits fail to meet one or two of the above-defined criteria or there are no data available for one or two of the categories. The probability that sand and gravel deposits exist within these units is moderate to high, but the limiting factors (for example shallow water-table, poor quality gravel, or limited thickness) may make them less valuable. These deposits typically have more variability in the sand-to-gravel ratio than those classed as primary potential sources. Corresponds to the "moderately desirable" potential-resource category employed by the Minnesota Department of Natural Resources.

Tertiary potential sources—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 due to the lack of exploratory drilling and pit exposures within these locations they are considered more speculative. These deposits typically have more variability in the sand-to-gravel ratio than those classed as primary and secondary potential sources, as well as varying amounts of overburden. Corresponds to the "less desirable" potential-resource category employed by the Minnesota Department of Natural Resources.

Active or intermittently active pit—Symbol may be accompanied by a 5-digit pit number if the pit is listed on the Minnesota Department of Transportation Aggregate Source Information System of aggregate resources. Table 1 shows a summary of attributes for each Minnesota Department of Transportation pit. Complete pit data for test hole logs and sieve and quality tests are available from the Minnesota Department of Transportation.

Inactive pit—Commonly overgrown or returned to cultivation

Auger hole—Shown if sand and gravel were encountered

BEDROCK ENDOWMENT

By

Terrence J. Boerboom

2003

Most of the bedrock in Pope County consists of felsic to intermediate-composition gneissic rocks and granitoid intrusive rocks. Elsewhere in Minnesota, such as in eastern Stearns County and in the Minnesota River Valley, these types of bedrock are extensively quarried for high-quality crushed-rock aggregate resources, as well as dimension stone. However, in Pope County the extremely thick cover of glacial drift (see Plate 2, Bedrock Topography and Depth to Bedrock) effectively eliminates any consideration of using the bedrock as a source of aggregate.

A small proportion of the bedrock in Pope County consists of mafic igneous intrusive rocks. These include small, ultramafic intrusions that bear similar geophysical characteristics to others outside of Pope County, which have been core-drilled for purposes of diamond mineral exploration. None of those drilled to date have been shown to be diamondiferous, and it is unlikely that those in Pope County would be any different. However, these small intrusions may be the target of future exploration activities, either for diamonds or other types of minerals.

Exploratory drilling has not tested the large, round intrusion (see Plate 2, Bedrock Geology; unit Pgb) that straddles the Pope County–Stearns County border, in southeastern Pope County. Geophysical data imply that this intrusion is mafic in composition, and thus could potentially be an exploration target for platinum-group minerals as well as copper and nickel. As with the rest of the bedrock in Pope County, this intrusion is deeply buried by glacial sediment, which may deter interest in exploring it for minerals potential. At best, exploration activity would probably be limited to a reconnaissance type of activity.

In summary, other than possible mineral exploration activity aimed at the mafic intrusive rocks within the county, the bedrock beneath Pope County is not likely to be utilized.

MNDOT pit number	Location (T-R-S)	Pit status	Map unit (see Plate 3)	Deposit class	Number of test holes	Average thickness of overburden (feet)	Average depth of holes (feet)	Average gravel content (percent)	Pit minimum gravel content (percent)	Pit maximum gravel content (percent)	Los Angeles Rattler[1]–size A (percent)	Los Angeles Rattler–size B (percent)	Los Angeles Rattler–size C (percent)	Spall[2] content–shale in sand (percent)	Spall content–shale in gravel (percent)	Spall content–iron oxide (percent)	Spall content–chert (percent)
61011	124-39-16	Inactive	hs	Secondary	27	1.6	9	45	5	69	24.4			2.8	3.3		0.1
61013	125-40-20	Inactive	hs	Secondary	79	2.5	19	43	1	84	25.4	24.5	30.2	3.2	4.1	0.7	
61016	125-37-11	Inactive	ogs	Secondary	21	1.3	12	26	5	55	23.3			1	0.6	0.5	
61019	124-36-15	Inactive	ogs	Secondary	6	1.5	9	51	23	71							
61023	125-37-06	Inactive	ogs	Secondary	38	2	15	35	4	62	26.1	26.5		1.9	1.3	1.3	
61024	125-37-06	Inactive	ogs	Secondary	38	2	15	35	4	62	26.1	26.5		1.9	1.3	1.3	
61030	124-39-15	Active	qc	Secondary	19	2.3	11	52	16	78							
61032	124-39-15	Active	qc	Secondary	8	8	17	56	33	73	20.5	22.4		0.3	0.1	0.3	trace
61035	123-39-10	Inactive	gcm	Tertiary	9	2.1	14	5	1	12							
61041	125-38-08	Inactive	qc	Secondary	18	1.1	16	35	9	57	23.5			0.8	0.3		0.3
61042	125-38-25	Inactive	gcm	Tertiary	17	2	20	22	5	31		24.8		2.5	2.5	0.4	
61045	124-36-22	Inactive	ogs	Secondary	40	2	17	31	4	55	24.6	25	23.8	0.6	0.3	0.2	
61046	125-38-08	Inactive	gp	Secondary	36	1.7	16	33	2	68	27.8	25.2	29.9	7.5	7.5	1.6	
61047	125-38-08	Inactive	gp	Secondary	36	1.7	16	33	2	68	27.8	25.2	29.9	7.5	7.5	1.6	
61048	126-36-15	Active	hs	Secondary	18	1.4	12	34	3	49	25.5			0	0.3	0.2	
61049	126-36-19	Inactive	ogs	Tertiary	34	1.7	15	36	21	56	24.7	25.7		0.8	0.2	0.3	
61050	124-37-28	Active	gcc	Primary	29	1.6	28	39	4	67	25.1	25.3		0.8	0.7	0.3	
61055	125-39-22	Active	qc	Secondary	15	2.4	26	23	2	60		22.8		0	0.2	0.1	
61057	125-39-22	Active	qc	Secondary	27	1.6	27	27	1	69	20.7	20.3		0.1	0.1	0	
61058	123-36-30	Inactive	gch	Primary	11	2	20	35	4	70		22.4		0.3	0.1	0.1	
61059	125-37-17	Inactive	ogp	Primary	56	2.4	23	52	1	84	20.6	23.1		1.4	0.7	0.9	
61060	125-37-17	Inactive	ogp	Primary	24	1.3	18	57	19	79	24.3	25.3		0.3	0.4	0.5	
61061	125-37-17	Inactive	ogp	Primary	14	2	24	37	14	60		24.7		0.3	0.4	0.2	
61062	126-37-27	Inactive	ogr	Secondary	11	2	19	31	3	49		21.6		0.2	0.2	0.3	
61063	125-39-29	Inactive	qc	Tertiary	19	1.9	25	33	5	67	21.5	22.7		4.1	3.7	1.2	
61064	124-36-21	Inactive	ogs	Secondary	25	1.8	14	28	4	38		23.5		0.5	0.5	0.6	
61065	124-36-21	Inactive	ogs	Secondary	25	1.8	14	28	4	38		23.5		0.5	0.5	0.6	
61066	124-38-36	Inactive	gp	Secondary	13	10	37	28	7	50		24.9		3	5.7	0.6	
61067	125-40-20	Inactive	qc	Secondary	47	2.3	14	53	31	86	27	24.3		3.6	2.3	1.4	0.2
61068	126-37-25	Inactive	ogs	Primary	54	1.8	18	41	8	69	23.7			0.9	0.3	0.5	0.1
61069	125-37-23	Inactive	ogs	Primary	23	1.5	20	47	12	65	23.8	24		1.6	0.3	0.2	0
61007	124-36-16	Inactive	ogs	Secondary	8	2.1	10	47	22	62							
61008	126-39-06	Inactive	gcm	Tertiary	21	1.5	11	30	15	44							
61009	126-39-06	Inactive	gcm	Tertiary	21	1.5	11	30	15	44							
61014	125-37-20	Inactive	ogs	Tertiary	26	2.7	8	33	3	81							
61018	126-38-29	Active	gp	Secondary	15	4	15	36	3	65							
61025	123-39-35	Inactive	gp	Tertiary	10	1.5	8	48	11	68							
61033	124-39-15	Inactive	qc	Secondary	18	1.6	11	21	6	35							
61034	124-39-15	Inactive	qc	Secondary	14	1.5	10	24	3	33							
61036	123-39-15	Inactive	gcm	Tertiary	6	2	12	29	18	38							
61037	125-39-25	Inactive	hsl	Tertiary	18	1	9	26	15	39							
61040	125-39-22	Inactive	qc	Secondary	21	1.5	23	33	1	74							
61051	125-38-02	Active	hc	Secondary	11	2	24	47	14	67							
61054	126-38-29	Active	gp	Tertiary	28	7	18	32	3	51							
61056	125-38-01	Inactive	hc	Secondary	19	1.6	16	43	12	66							
61001	124-39-15	Active	qc	Secondary													
61029	123-39-33	Inactive	bd	Tertiary													
61071	125-39-23	Active	qc	Secondary													
61072	125-36-17	Inactive	ogs	Tertiary													

Table 1. Summary of gravel pit data for Pope County. Pit test results and calculated averages were compiled from the Minnesota Department of Transportation (MNDOT) gravel pit survey sheets. The entire data set is available from the Minnesota Department of Transportation. Locations are given as township, range, and section (T-R-S); in Pope County, all townships are north and all ranges are west. Map unit labels are the same as on the Surficial Geology map (Plate 3), where the descriptions can be found.

Rating factors	Primary	Secondary	Tertiary
1. Sand and gravel thickness	>20 feet	1 or 2 of the primary rating factors are not met or no data exist	3 or more of the primary rating factors are not met or no data exist
2. Overburden thickness	<5 feet		
3. Gravel retained on #10 sieve	>35 percent		
4. Depth to water-table	>20 feet		
5. Quality			
LAR[1]	<40 percent		
Total spall[2]	<1.5 percent		

Table 2. Sand and gravel potential-source rating factors.

NATURAL-AGGREGATE ENDOWMENT

By

Alan R. Knaeble and Kenneth L. Harris

2003

INTRODUCTION

The geologic endowment of natural aggregate in Pope County consists of sand and gravel deposited by streams and lakes, both of which are products of glacial meltwater and postglacial precipitation. Gravel determined by standard test methods[1, 2] to be of moderate to good quality is relatively common in some areas of the county. Generally, the gravel in the eastern portion of the county is of higher quality than that in the western regions because it contains less deleterious materials (for example shale, iron oxide, chert, coal, or clayey limestone), particularly shale. Sand and gravel deposits and gravel-less sand deposits are used mainly for road construction and maintenance of local township, county, and state roads, and also for general construction in small urban communities. Private small pits of variable quality may commonly be used as local sources of material for general farm use (such as fill, road maintenance, or concrete).

EVALUATION CRITERIA

Shown on this map are three units, primary, secondary, and tertiary, in which there is some potential for the existence of commercially viable gravel and sand deposits (as judged solely from geologic criteria). Where available, Minnesota Department of Transportation data that describe aggregate quantity and quality for specific pits were used to identify the units that have the greatest potential. The map units rated "primary" have demonstrated the highest aggregate potential as documented by the Minnesota 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 to acknowledge the possibility that this material may extend beyond the pit boundaries to adjacent areas within the unit. Units rated "secondary" or "tertiary" that do not have demonstrated potential as indicated by Minnesota Department of Transportation data rated lower because they are somewhat speculative, but they may still harbor high potential aggregate deposits. In all cases, site-specific evaluation is required. The areas of the county that have no assigned map unit are interpreted to have little or no significant aggregate potential. This does not exclude the possibility that minor local deposits of sand and gravel may be found in these areas.

The map units on this plate were determined using the following criteria (listed in order of importance):

- Minnesota Department of Transportation gravel pit sheet data and test results that include sand and gravel thickness, average percentage of gravel retained on the number 10 sieve (2-millimeter mesh), depth to water-table, thickness of overburden, and material quality testing, which includes the percentage of shale retained on the number 4 sieve (4.75-millimeter mesh), total spall content[2], and hardness test (Los Angeles Rattler[1]) results (Table 2).
- Field descriptions of observed pits, including pit size, gravel amount estimate, and determinations of rock type percentages.
- Geologic unit correlation from the Surficial Geology map (Plate 3). These include:
  - A. Glacial meltwater stream sediment shown by map units qc, gf, gcc, ogc, ogo, ogr, ogs, and ogp; and Holocene stream sediment, which includes reworked glacial stream sediment, indicated by map units hc, ha, hs, qc, and ogp. These stream sediments are predominantly sorted sand and gravel with little silt and clay and are commonly found along modern day stream channels and in broad outwash plains (particularly in the eastern portion of the county).
  - B. Ice-contact deposits, included in units hs, op, gcc, gf, and ogr, and related landforms such as eskers, collapsed glacial stream sediment, collapsed glacial lake sediment, and ice-marginal fans.
  - C. Glacial lake deposits shown by units bsl, bd, and gf; and Holocene lake deposits indicated by units hsl and hns. Included in these sediments are beach ridge sand and gravel, sorted sand, and occasionally silt and clay.
- Geomorphic interpretation using topographic maps.

EVALUATION

Potential sources of sand and gravel aggregate at or near the land surface in Pope County are almost exclusively composed of materials deposited by meltwater and ice of the numerous phases of the most recent ice advance, the Des Moines lobe (see Plate 3, Surficial Geology). Shale, which is an undesirable component in high-quality gravel, is abundant to common in the glacial deposits in the western region of the county, but was found to be common to uncommon in the eastern region. This difference reflects the changing source-rock composition of the phases of the Des Moines lobe.

In a few areas (along the Ashley Creek channel, the northern and western sides of Lake Minnewaska, and in other isolated areas where the Des Moines lobe sediments are not as thick), shale-free sand and gravel deposits from an older ice lobe that deposited the Crow Wing River group (Plate 3, Surficial Geology) are at or near the surface, resulting in an aggregate source of higher quality. A high water-table along Ashley Creek and insufficient data in the other areas limited the extent of where these areas could be mapped as primary potential sources.

The large area in the southeast corner of the county mapped as a secondary potential source is the Brooten–Belgrade outwash plain. Glacial meltwater was channeled through this area flowing to the southwest, depositing a broad, 30 to 60 foot (9 to 18 meter) thick sequence of sand and gravel. Material quality is generally good, but variability in the amounts of gravel and in the depth to water table, combined with areas of insufficient data precluded a primary rating. Abundant sand and gravel in the Blue Mounds township region was deposited by meltwater and by ice contact processes. Variability in the amount of gravel, thickness of the deposit, and in quality (higher shale percentages are common in some pits) restricted this area from receiving a higher rating.

The flat-topped hill terrain in the vicinity of Lake Johanna and Gilchrist Lake contains a variety of deposits. The tertiary designation was used because some pits and exposures had high sand-to-gravel ratios, and others appeared as isolated pockets of sand and gravel within silty and clayey glacial sediment. Unmapped portions of this area may contain local deposits of sand or a sand and gravel mixture.

Channel deposits along the northern extent of the Chippewa River were mapped as secondary sources. High shale content in the materials and the possibility of a high water table were restrictive factors and accounted for this rating. At the end of the last ice advance the Chippewa River meltwater entered Glacial Lake Benson just northwest of Lake Emily. From there south to the county border sandy deposits attributed to this glacial lake are widespread. Post-glacial deposits of the Chippewa River as it cut through this lake plain are less desirable than those to the north because they may contain more sand and less gravel.

ACKNOWLEDGMENTS

Randy Tilseth of the Minnesota Department of Transportation provided specifications for aggregate issued by that department. Thanks are also extended to all gravel pit owners who granted permission to access their pits.

[1]**Los Angeles Rattler test** (LAR; AASHTO test T 96, ASTM test C 131)—This is a standard method of testing the resistance of aggregate to abrasion. Coarse aggregate is rotated in a steel cylinder with steel balls for a specified time. The percentage of material abraded from the coarse aggregate originally placed in the cylinder, expressed as percentage loss, is the LAR value; the more resistant or tough the aggregate, the smaller the LAR value. A higher percentage of loss (more than 35 to 40 percent) indicates a higher percentage of softer, weathered, or more brittle rock. The LAR test is typically performed at three aggregate-size ranges: size A, 9.5 to 37.5 millimeters; size B, 9.5 to 19.0 millimeters; and size C, 4.75 to 9.5 millimeters.

[2]**Spall material**—A term used by the Minnesota Department of Transportation for rock particles, such as shale, soft iron oxide, coal and lignite, unsound chert, clay balls and lumps, and other particles that have similar characteristics and soften and expand when wet, causing a popout or spall in hardened concrete or bituminous mix. The percentage of shale in a sample is determined for the sand fraction and for the gravel fraction (fraction retained on the 4.75-millimeter or #4 sieve) of the sample. Shale is separated from the rest of the sample by floatation using a heavy liquid (specific gravity of 1.95), but the other particles, mainly chert and iron oxide, are picked from the sample individually. Amounts are reported by mass. Current Minnesota Department of Transportation requirements for total maximum spall in total sample or in the fraction retained on the number 4 sieve range from 1.0 to 5.0 percent dependent on the mixture type. Clay lumps in the fraction retained on the number 4 sieve must be less than 0.5 percent by mass. The shale content of the fraction passing the number 4 screen must be 5 percent or less dependent on mixture type.

REFERENCES

Minnesota Department of Transportation, 2002, MN/DOT standard specifications for construction books: St. Paul, Minn., <http://www.dot.state.mn.us/tecsup/spec/index.html>.

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.

A SELECTION OF MINNESOTA DEPARTMENT OF TRANSPORTATION SPECIFICATIONS FOR AGGREGATE

(Minnesota Department of Transportation, 2002)

AGGREGATE CLASSES

CLASS A—Consists of "…crushed quarry or mine trap rock (basalt, diabase, gabbro or other related igneous rock types), quartzite, or granite" (Minnesota Department of Transportation, 2002, p. 812). These are rocks that are more uniform throughout a quarry and generally have fewer deleterious qualities. No class A aggregate has been identified in Pope County.

CLASS B—Consists of "…all other crushed quarry or mine rock; i.e., carbonates, rhyolite, schist" (Minnesota Department of Transportation, 2002, p. 812). 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 can then freeze and crack pavement. No class B aggregate has been identified in Pope 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

CLASS R—Recycled concrete

GRADED AGGREGATE USED IN ASPHALT MIXTURES

Quality tests performed on crushed rock, natural gravel, and mixtures.

LOS ANGELES RATTLER[1] loss in the coarse fraction (material retained on the 4.75-millimeter 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 sieve—gravel sized or coarser) shall not exceed:

a. More than 14 percent on the 19- to 12.5-millimeter and larger fractions;
b. More than 18 percent on the 12.5- to 9.5-millimeter fraction;
c. More than 23 percent on the 9.5- 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[2] AND LUMPS

Mixtures for low-traffic surfaces—
Total spall in total sample 5.0%
Lumps in fraction retained on 4.75-millimeter sieve 0.5%

Mixtures for medium-traffic surfaces—
Total spall in fraction retained on 4.75-millimeter sieve 2.5%
Shale content of fraction passing 4.75-millimeter sieve 5.0%
Lumps in fraction retained on 4.75-millimeter sieve 0.5%

Mixtures for high-traffic surfaces—
Total spall in total sample 1.0%
Lumps in fraction retained on 4.75-millimeter sieve 0.5%