

## PROCEDURE FOR THE PETROGRAPHIC ANALYSIS OF COARSE AGGREGATE

### 1. SCOPE

1.1 This procedure outlines the method to be employed in the petrographic analysis of coarse aggregate. The procedure appraises the quality of coarse aggregate, and provides a numerical means (in terms of a petrographic number, or P.N.) of expressing and comparing the quality of samples from the same or different sources.

1.2 This procedure does not attempt to describe the techniques used in the geological classification of the aggregate particles, since it is assumed that the examination will be performed by persons qualified to do so by experience and training. The subsequent classification of aggregate particles into quality types employs index tests related to their strength. Sets of reference samples for the petrographic analysis can be obtained from the Petrographer, Soils and Aggregates Section, Engineering Materials Office, 1201 Wilson Ave., Downsview, Ontario, M3M 1J8.

### 2. RELEVANT DOCUMENTS

2.1 ASTM C 294, C 295

2.2 MTO LS-602, LS-616

2.3 EM - 91, Petrographic Examination of Aggregate and Concrete in Ontario, Engineering Materials Office, Ministry of Transportation.

### 3. DEFINITION

3.1 Siliceous Aggregates: means rock particles containing or composed of silica ( $\text{SiO}_2$ ) or minerals with silica in the crystal structure as silicate ( $\text{SiO}_4$ ). Siliceous aggregates include the following Type Numbers given in Figure 1 and Table 1: 03, 22, 06, 04, 05, 08, 07, 09, 10, 30, 29, 25, 34, 27, 28, 46, 56, 50, 55, 51, 48, 63, 71, 81, 82, 73, 74, 33, 86, 84, 97, 87, 32, and 64.

### 4. APPARATUS

4.1 HAND LENS: 10x magnification.

4.2 ALNICO MAGNET.

4.3 POCKET KNIFE: Good quality with a blade hardness of between 5.5 and 6 on Moh's scale.

4.4 ANVIL & HAMMER: Suitable for breaking aggregate particles.

4.5 HYDROCHLORIC ACID: Technical grade, 5 % by volume, in polyethylene squeeze-type bottle with spout.

- 4.6 STEREOSCOPIC MICROSCOPE: 4x to 25x final magnification, with illumination source.
- 4.7 BALANCE: Accurate to 0.1 g and of sufficient capacity,
- 4.8 LIGHT SOURCE: Capable of providing excellent illumination of working area.

## 5. PREPARATION OF SAMPLE

5.1 A representative sample of oven dried aggregate shall be prepared to the following approximate masses:

Pass	Retained	Approx. Mass, g
75 mm	19.0 mm	10,000
53 mm	19.0 mm	5000
37.5 mm	19.0 mm	4000
26.5 mm	19.0 mm	3000
19.0mm	9.5 mm	1000
13.2 mm	9.5 mm	500
9.5 mm	6.7 mm	200
6.7 mm	4.75 mm	75

*Note 1: Generally this examination is performed on the pass 19.0 mm retained 9.5 mm material (full fraction), which should consist of pass 19.0 mm retained 16.0 mm, pass 16.0 mm retained 13.2 mm and pass 13.2 mm retained 9.5 mm material proportioned according to the sieve analysis of the aggregate. The pass 13.2 mm retained 9.5 mm material should not exceed 500 g in weight. If the full fraction constitutes less than about 68.5 percent of the sample, the pass 9.5 mm retained 6.7 mm fraction shall also be examined. If these fractions together constitute less than about 68.5 percent of the sample, the pass 6.7 mm retained 4.75 mm fraction shall also be examined. Each sieve size examined should contain a minimum of 200 particles.*

## 6. TEST PROCEDURE

- 6.1 The sample shall be spread on a tray or other flat working surface.
- 6.2 If required, the sample shall be examined visually for angularity and shape characteristics and an estimate made and noted of the percentage of crushed, as well as flat and elongated, particles.
- 6.3 The aggregate shall be examined for coatings (such as clay), cementations and encrustations which may affect the bond with Portland cement paste or asphalt cement. The type of coating and the degree of adhesion to the aggregate shall be noted.

6.4 If clay balls or other particles, which may break down in water or with normal handling are present, these particles shall be separated out.

6.5 The sample shall be washed to remove clay and dust coatings. In addition, when the sample contains carbonates and or metavolcanics it shall be soaked for a period of at least one hour. Following immersion, each particle shall be quickly surface dried and then examined, and tested for scratch.

*Note 2: Soaking will cause clay, shale, and shaley, slightly shaley or micaceous particles to soften, making recognition easier.*

6.6 The washed sample shall be spread on a flat surface covered with paper or cloth towel to absorb excess water.

6.7 Each particle in the sample shall be classified into a rock type listed on Form PH-CC-343 (Figure 1) or the supplementary rock type list (Table 1). A guide is provided as an appendix to this procedure.

*Note 3: Index tests and microscopic examination will usually be sufficient to classify a rock particle. If not, the particle shall be referred to a petrographer for identification (possibly requiring detailed petrographic study).*

6.8 In the classification of each particle, the following features may be relevant:

6.8.1 Strength; features such as fossils and clay or shale partings (including stylolites) may constitute weaknesses.

6.8.2 Relative Density.

6.8.3 Shape.

6.8.4 Texture, including porosity and cementation.

6.8.5 Colour.

6.8.6 Mineralogy.

6.8.7 Structure, including bedding and foliation.

6.8.8 Effervescence with acid.

6.8.9 State of weathering.

6.8.10 Magnetism.

6.9 On the completion of the examination, each group of classified particles shall be weighed to the nearest 0.1 g and the weights recorded on Form PH-CC-343 (Figure 1). If any rock types are present which are not found on this form, the category in which they shall be recorded will be found in the supplementary rock type list (Table 1).

## 7. CALCULATION

7.1 The percentage of each rock type shall be calculated to the nearest 0.1 percent. The percentages of good, fair, poor and deleterious particles shall be calculated. The sum of the sub-totals shall be 100 percent.

7.2 The petrographic number of aggregates for use in hot mix asphalt, surface treatment and concrete shall be calculated as the sum of the products of the percentage of each petrographic category (good, fair, poor and deleterious) and the appropriate factor for each category (1,3,6, and 10, respectively).

7.3 If the material is to be used for granular base or sub-base, a correction shall be applied which reflects the differing environmental conditions in which the material is used. The percentage of each rock type shall be multiplied by the appropriate correction factor (0, 2, 3, 5, 7, or 9) shown on Form PH-CC-343 and the supplementary rock type list. The sum of the values obtained shall be subtracted from the petrographic number for hot mix asphalt, surface treatment and concrete to obtain the corrected petrographic number for granular use.

*Note 4: The use of a petrographic number to classify aggregate for use in granular base and sub-base has been discontinued by MTO.*

7.4.1 When the test is performed on more than one size fraction, a weighted average petrographic number shall be calculated by multiplying the percentage (based on the 'as received' coarse aggregate sample grading) of each sieve fraction by the petrographic number for that fraction, adding these products, and dividing by 100.

7.4.2 For the purpose of calculating the weighted average, any fractions (not tested) that contain less than 5 percent of the 'as received' sample shall be considered to have the same value as the average of the next smaller and the next larger fraction or, if one of these fractions is missing, to have the same value as the next larger or smaller fraction, whichever is present.

## 8. REPORTING OF RESULTS

8.1 The report of the examination should include the following:

8.1.1 The aggregate source name, location, and Mineral Aggregate Inventory Data Bank (MAIDB) number.

8.1.2 The laboratory sample number.

8.1.3 The date, the fraction examined, and the name of the analyst.

8.1.4 The percentages (to the nearest 0.1 percent) of each rock type and of good, fair, poor, and deleterious particles.

8.1.5 The petrographic numbers (to the nearest whole number) for hot mix asphalt, surface treatment and concrete, and for granular base and sub-base.

8.1.6 The weighted average petrographic numbers (to the nearest whole number), when the test is performed on more than one size fraction.

8.1.7 When required, the percent by mass of siliceous aggregate.

## 9. GENERAL NOTES

9.1 In the event that there are a number of particularly absorptive particles, they should be dried before weighing so that water absorbed during washing will not significantly influence the mass.

9.2.1 Due to the time-consuming nature of petrographic examination on the smaller coarse aggregate sizes, a shorter procedure is usually used.

9.2.2 A full petrographic examination shall always be performed on the largest aggregate size of a sample. If smaller sizes are also to be tested, they may be separated into the petrographic categories 'good' and 'deleterious' without separation into individual rock types. The nature of the material in the 'good' and 'deleterious' categories will normally be apparent from the complete petrographic analysis on the largest size. Those particles that fall into the 'fair' and 'poor' categories must be separated into their individual rock types.

9.2.3 If the nature of the 'good' and 'deleterious' material is questionable, a full petrographic analysis of the smaller sizes must be performed.

9.3 The factors applied to each rock type are based on laboratory studies and in-service performance for the intended use and prevailing conditions in Ontario. These factors may not apply under other conditions and in other areas. The factors are subject to periodic review, and shall be changed when necessary to reflect current experience.

9.4 The petrographic factors take only physical properties into account. The possibility of the aggregate being alkali-reactive in concrete is not considered.

## 10. PRECISION

10.1 The petrographic number of a stockpile of coarse aggregate varies by up to 20 on either side of the mean (19 times out of 20).

Ministry of Transportation		COARSE AGGREGATE PETROGRAPHIC ANALYSIS – MTO LS609			
SOURCE NAME _____		MAIDB NO. _____			
LOCATION _____		LAB. NO. _____			
DATE _____		FRACTION _____		ANALYST _____	
TYPE	TYPE NO.	MASS	%	GRANULAR CORRECTION	
CARBONATE (hard; silty, hard)	01			-	-
CARBONATE (surf. weath.; silty, surf. weath.; med. hard; silty, med. hard)	20			-	-
CARBONATE (sandy, hard or medium hard)	02			-	-
CARBONATE (slightly cherty: <5% chert)	21			-	-
MARBLE (hard or medium hard)	23			-	-
CONGLOMERATE-SANDSTONE-ARKOSE (hard)	03			-	-
CONGLOMERATE-SANDSTONE-ARKOSE (medium hard)	22			-	-
GREYWACKE-ARGILLITE (hard or medium hard)	06			-	-
GNEISS-AMPHIBOLITE-SCHIST (hard)	04			-	-
QUARTZITE	05			-	-
GRANITE-DIORITE-GABBRO (hard)	08			-	-
VOLCANIC (hard or medium hard)	07			-	-
TRAP (≤20% sulphide)	09			-	-
QUARTZ (vein or pegmatitic)	10			-	-
TOTAL GOOD AGGREGATE	-			-	-
CARBONATE (soft; silty, soft; slightly shaley)	35			X2	
CARBONATE (soft, pitted)	41			X2	
CARBONATE (deeply weathered; silty, deeply weathered)	42			-	-
CARBONATE (sandy, soft)	40			X2	
MARBLE (brittle)	24			X2	
CHERT-CHERTY CARBONATE (<20% leached chert)	26			X2	
CONGLOMERATE-SANDSTONE-ARKOSE (brittle)	30			X2	
GREYWACKE (brittle)	29			X2	
ENCRUSTATION	52			X2	
GNEISS-AMPHIBOLITE-SCHIST (brittle)	25			X2	
ARGILLITE (medium soft)	34			X2	
GRANITE-DIORITE-GABBRO (brittle)	27			X2	
VOLCANIC (soft)	28			X2	
TOTAL FAIR AGGREGATE	-			-	-
CARBONATE (shaley; clayey; silty, clayey)	43			-	-
CARBONATE (ochreous; sandy, ochreous)	44			-	-
MARBLE (friable)	49			X3	
CHERT-CHERTY CARBONATE (≥20% leached chert)	45			X5	
CONGLOMERATE-SANDSTONE-ARKOSE (friable)	46			X3	
SILTSTONE	56			X3	
CEMENTATION (partial)	53			X3	
CEMENTATION (total)	54			-	-
GNEISS-AMPHIBOLITE (friable)	50			X3	
SCHIST (soft)	55			X3	
GRANITE-DIORITE-GABBRO (friable)	51			X3	
VOLCANIC (very soft, porous)	48			X3	
TOTAL POOR AGGREGATE	-			-	-
OCHRE	60			-	-
SHALE	61			-	-
CLAY	62			-	-
VOLCANIC-GNEISS-SCHIST (decomposed)	63			-	-
TOTAL DELETERIOUS AGGREGATE	-			-	-
% GOOD _____ x 1 = _____		TOTALS			
% FAIR _____ x 3 = _____					
% POOR _____ x 6 = _____					
% DELETERIOUS _____ x 10 = _____					
HOT MIX, SURF. TREATMENT AND CONCRETE P.N. _____		EST. PERCENT CRUSHED _____			
		EST. PERCENT FLAT AND ELONGATED _____			
		CORRECTED GRANULAR P.N. _____			

PH-CC-343 93-06

Made from recovered materials

Figure 1 MTO Form PH-CC-343

Table 1 Supplementary Rock Type List

C A T E G O R Y	TYPE	TYPE NUMBER	CORRECTION FOR GRANULAR
G O O D	IRON FORMATION (hard; sl. weath.)	71	-
	GYPSITE (< 10 % gypsum)	77	-
	SEDIMENT: SIBLEY GROUP (hard)	80	-
	FLINT/JASPER	81	-
F A I R	SULPHIDE	72	-
	IRON FORMATION (mod. weathered)	82	-
	VOLCANIC (glassy)	73	X2
	VOLCANIC (ochreous)	74	X2
	TRAP (21-74 % sulphide)	33	X2
	SEDIMENT: SIBLEY GROUP (med. hard)	83	-
P O O R	GYPSITE (10-49 % gypsum)	78	X3
	ARGILLITE-TUFFITE-SLATE (soft)	86	-
	IRON FORMATION (highly weathered)	84	-
	SEDIMENT: SIBLEY GROUP (soft)	85	-
	GREYWACKE (friable)	97	X3

D E L E T E R I O U S	IRON FORMATION (decomposed)	87	-
	ARGILLITE-TUFFITE-SLATE (very soft)	32	-
	GYPSITE (> 49 % gypsum)	79	-
	SEDIMENT: SIBLEY GROUP (very soft)	88	-
	SLAG-GLASS (in non-slag aggregate)	92	X9
	COAL-COKE-CINDER	31	X7
	TALC	64	-

## **APPENDIX TO PROCEDURE FOR THE PETROGRAPHIC ANALYSIS OF COARSE AGGREGATE (TYPE DESCRIPTIONS)**

### **DISCUSSION**

In the petrographic analysis, aggregate particles are initially subjected to a geological classification. Particles are then categorized into types, using descriptors such as 'hard', 'soft', 'brittle', 'friable', 'surface weathered', 'deeply weathered', 'decomposed', etc. For the purposes of standardization, descriptions of the various types are presented in this appendix.

Index tests related to the strength of the aggregate particles, such as scratching, scraping, peeling and plucking using a knife blade, are employed in this classification. Scratching, scraping, and peeling determine the application of hardness descriptors; and plucking determines the application of descriptors such as 'brittle' and 'friable'. Each rock group, such as carbonate, sandy carbonate, marble, volcanic, gneiss, etc., is described separately so as to highlight the decreasing quality of the group through categories 'good' to 'deleterious'. This enables an aggregate to be classified on a systematic basis.

Due to the subjective nature of this test method, descriptions of types contained in this appendix should be considered only as a guideline. The petrographic examination is largely dependent on the experience of the analyst and, where possible, should be complemented by routine tests and/or performance data. In specific cases (especially those of rocks whose performance is unfamiliar to the analyst) additional testing including the study of thin sections may be necessary. A freeze-thaw test conducted on medium hard and slightly shaley carbonate can be used to determine if the shale seams are planes of weakness, and therefore whether or not the particles are classified correctly; the material should be immersed in a 3 % sodium chloride solution in a pan and subjected to five cycles, each cycle consisting of approximately 16 hours of freezing followed by approximately 8 hours of thawing at room temperature.

### **CARBONATE, SILTY CARBONATE, SILTSTONE, AND CLAY**

#### **GOOD**

1. Carbonate (hard): high strength; can be scratched (relatively thin scratch); typically unweathered
1. Carbonate (silty, hard): high strength; can be scratched; (relatively thin scratch); raspy sound when scratched; commonly greenish grey; typically unweathered
20. Carbonate (medium hard): high strength; can be scratched (relatively thick scratch)
20. Carbonate (silty, medium hard): high strength; can be scratched (relatively thick scratch); raspy sound when scratched; commonly greenish grey

- 20. Carbonate (surface weathered): mainly high strength; can be scratched; no more than 33 percent of particle consists of medium to low strength weathered material
- 20. Carbonate (silty, surface weathered): mainly high strength; can be scratched; raspy sound when scratched; commonly greenish grey; no more than 33 percent of particle consists of medium to low strength weathered material

FAIR

- 35. Carbonate (soft): medium strength; uniform consistency; can be scratched and scraped with ease; cannot be peeled
- 35. Carbonate (silty, soft): medium strength; can be scratched with ease and scraped with some difficulty; may contain minor low strength zones which can be scraped with ease; raspy sound when scratched; commonly greenish grey
- 41. Carbonate (soft, pitted): medium strength; can be scratched with ease and scraped with some difficulty; moderately pitted
- 42. Carbonate (deeply weathered): more than 33 percent of particle consists of medium to low strength weathered material
- 42. Carbonate (silty, deeply weathered): more than 33 percent of particle consists of medium to low strength weathered material; raspy sound when scratched; commonly greenish grey

POOR

- 43. Carbonate (clayey): contains between 33 and 75 percent very low strength material; can be scraped and peeled with ease
- 43. Carbonate (silty, clayey): contains between 33 and 75 percent very low strength material; can be scraped and peeled with ease; raspy sound when scratched
- 44. Carbonate (ochreous): contains between 33 and 75 percent ochreous material
- 56. Siltstone: fissile (tends to separate readily along thin bedding planes on which mica flakes can commonly be seen); medium to low strength; poorly cemented; friable (many pieces can be plucked easily from particle)

DELETERIOUS

- 62. Clay: greater than 75 percent of particle consists of very low strength material; can be peeled with ease and at times can be broken with the fingers or cut completely through; includes kaolin

## **SANDY CARBONATE**

### GOOD

2. Carbonate (sandy, hard or medium hard): high strength (matrix material may be slightly weaker than quartz grains); can be scratched with some difficulty; raspy sound when scratched; ranges from no weathering to thin surface weathering; contains 5 to 49 percent sand-sized quartz grains

### FAIR

40. Carbonate (sandy, soft): medium strength; can be scratched with ease and scraped with some difficulty; may contain minor low strength zones which can be scraped with ease; raspy sound when scratched; contains 5 to 49 percent sand-sized quartz grains

### POOR

44. Carbonate (sandy, ochreous): contains between 33 and 75 percent ochreous material; contains 5 to 49 percent sand-sized quartz grains

## **MARBLE**

### GOOD

23. Marble (hard or medium hard): high strength; can be scratched; intact (edges and corners cannot be plucked)

### FAIR

24. Marble (brittle): medium strength; can be scratched with ease and scraped with some difficulty; brittle (edges and corners can be plucked); may have partial to total thin surface weathering

### POOR

49. Marble (friable): low strength; friable (many pieces can be plucked easily from particle) to highly friable (particle crumbles totally when plucked); includes cleavable calcite

## **SHALEY CARBONATE AND SHALE** (See Table 2 for petrographic classification)

### GOOD

20. Carbonate (medium hard): high strength; can be scratched (relatively thick scratch)

### FAIR

35. Carbonate (slightly shaley): medium strength; can be scratched with ease and scraped with some difficulty; generally shows grey or brown (sometimes greasy) streak when scratched

POOR

43. Carbonate (shaley): low strength; can be scraped with ease and peeled with some difficulty; generally shows grey, brown or black (sometimes greasy) streak when scratched

DELETERIOUS

61. Shale: low to very low strength; can be scraped and peeled with ease; sometimes greasy to touch

**CHERT AND CHERTY CARBONATE**

GOOD

21. Carbonate (slightly cherty: <5 % chert): high strength; hard and/or slightly weathered carbonate; particle contains less than 5 percent chert

FAIR

26. Chert-Cherty Carbonate (<20 % leached chert): high strength; hard and/or slightly weathered carbonate; particle contains 5 percent or more chert, but less than 20 percent of the particle is leached (i.e., absorptive) chert which can generally stick to the tongue

POOR

45. Chert-Cherty Carbonate ( $\geq 20$  % leached chert): high to medium strength; particle contains 20 percent or more leached (i.e., absorptive) chert, which can generally stick to the tongue

*Note 5: The classification of semi-leached chert as leached chert or unleached chert should be based on the rate of absorption.*

**CONGLOMERATE-SANDSTONE-ARKOSE**

GOOD

3. Conglomerate-Sandstone-Arkose (hard): high strength; cannot be scratched; intact (edges and corners cannot be plucked)
22. Conglomerate-Sandstone-Arkose (medium hard): high strength; generally cannot be scratched, although cementing material may be scratched with some difficulty; some edges and corners can be plucked with difficulty

FAIR

30. Conglomerate-Sandstone-Arkose (brittle): medium to high strength; generally cannot be scratched, although cementing material may be scratched with moderate ease; brittle (edges and corners can be plucked)

POOR

46. Conglomerate-Sandstone-Arkose (friable): low strength; generally poorly cemented; friable (many pieces can be plucked easily from particle) to highly friable (particle crumbles totally when plucked)

## **QUARTZITE**

### **GOOD**

5. Quartzite: very high strength; cannot be scratched

## **GNEISS-AMPHIBOLITE-SCHIST**

### **GOOD**

4. Gneiss-Amphibolite-Schist (hard): mainly very high strength; generally cannot be scratched; minor medium to high strength (e.g., micaceous and chloritic) zones which can be scratched and scraped with some difficulty; may have partial thin surface weathering

### **FAIR**

25. Gneiss-Amphibolite (brittle): mainly medium to high strength; generally cannot be scratched; brittle (edges and corners can be plucked); minor medium to low strength zones which can be plucked with ease; may have partial to total, thin, surface weathering
25. Schist (brittle): medium strength; can be scratched with moderate ease; brittle (edges and corners can be plucked); may contain minor more friable zones which can be plucked and scraped with ease

### **POOR**

50. Gneiss-Amphibolite (friable): low strength; friable (many pieces can be plucked easily from particle) to highly friable (particle crumbles when plucked)
55. Schist (soft): low strength; can be scraped and plucked with ease; contains chloritic and/or micaceous zones which can be peeled with ease

### **DELETERIOUS**

63. Schist (decomposed): very low strength; can be crumbled with the fingers; high mica or chlorite content; low quartz and feldspar content
63. Gneiss (decomposed): very low strength; can be crumbled with the fingers; high mica content; low quartz and feldspar content

## **GREYWACKE-ARGILLITE-TUFFITE-SLATE**

### **GOOD**

6. Greywacke (hard or medium hard): high strength; can be scratched with difficulty; some edges and corners can be plucked with difficulty
6. Argillite (hard or medium hard): high to very high strength; can be scratched with difficulty

### **FAIR**

29. Greywacke (brittle): medium to high strength; can be scratched with moderate ease and scraped with some difficulty; brittle (edges and corners can be plucked)

34. Argillite (medium soft): medium strength; can be scratched with moderate ease and scraped with some difficulty

POOR

97. Greywacke (friable): low strength; friable (many pieces can be plucked easily from particle) to highly friable (particle crumbles when plucked)
86. Argillite-Tuffite-Slate (soft): low to medium strength; can be scratched and scraped with ease; fissile (particle breaks along closely spaced fractures, and shatters when struck by a hammer); generally characterized by length to thickness ratio less than 4 to 1

DELETERIOUS

32. Argillite-Tuffite-Slate (vey soft): low to very low strength; can be scraped and peeled with ease; very fissile (particle breaks readily along very closely spaced fractures, and shatters easily when struck by a hammer); rusty weathering stains penetrate into the particle; generally characterized by length to thickness ratio greater than 4 to 1

**GRANITE-DIORITE-GABBRO**

GOOD

8. Granite-Diorite-Gabbro (hard): mainly very high strength; generally cannot be scratched; minor medium strength (e.g., micaceous and chloritic) zones which can be scratched and scraped with some difficulty; may have partial thin surface weathering

FAIR

27. Granite-Diorite-Gabbro (brittle): mainly medium to high strength; generally cannot be scratched; brittle (edges and corners can be plucked); minor medium to low strength zones which can be plucked with ease; may have partial to total thin surface weathering

POOR

51. Granite-Diorite-Gabbro (friable): low strength; friable (many pieces can be plucked easily from particle) to highly friable (particle crumbles when plucked)

**TRAP (INCLUDES VERY HARD BASALT AND FINE GRAINED DIABASE/GABBRO)**

GOOD

9. Trap (20 % sulphide): very high strength; faint scratch may be possible; fine grained; dark coloured; unweathered; may contain magnetite, hard epidote, garnet, and/or up to 20 % sulphide minerals such as pyrite

FAIR

33. Trap (21-74 % sulphide): very high strength; faint scratch may be possible; fine grained; dark coloured; generally unweathered; contains 21 to 74 percent sulphide minerals such as pyrite; may contain magnetite, hard epidote, and/or garnet

## **ENCRUSTATION**

### **FAIR**

52. Encrustation: 33 percent or more of particle is covered by a coating, usually calcium carbonate (25 percent in the case of a thick coating)

## **CEMENTATION**

### **POOR**

53. Cementation (partial): a group of particles cemented together, usually by calcium carbonate; one dominant host particle
54. Cementation (total): a group of particles cemented together, usually by calcium carbonate; no dominant host particle

## **VOLCANIC**

### **GOOD**

7. Volcanic (hard or medium hard): mainly very high strength; generally cannot be scratched; minor medium to high strength zones which can be scratched and scraped with some difficulty; may have partial, thin, surface weathering

### **FAIR**

28. Volcanic (soft): medium strength; can be scratched with moderate ease and scraped with some difficulty; may contain minor low strength zones which can be gouged
73. Volcanic (glassy): cannot be scratched; conchoidal to semi-conchoidal fracture; includes obsidian
74. Volcanic (ochreous): contains between 25 and 50 percent ochreous material

### **POOR**

48. Volcanic (very soft): low strength; can be scraped with ease and peeled with some difficulty; may contain up to 75 percent ochre
48. Volcanic (porous): porous; low strength; can be scratched and scraped with ease; may contain up to 75 percent ochre

### **DELETERIOUS**

63. Volcanic (decomposed): very low strength; can be peeled with ease and crumbled with fingers

## FLINT/JASPER AND IRON FORMATION

### GOOD

- 71. Iron Formation (hard): high strength; cannot be scratched; unweathered
- 71. Iron Formation (slightly weathered): mainly high strength; can be scratched with difficulty; less than 5 percent of particle consists of penetrating zones of low to medium strength weathered material which can be scraped or gouged; may have partial to total thin surface weathering (rusty stains)
- 81. Flint/Jasper: high strength; cannot be scratched

### FAIR

- 82. Iron Formation (moderately weathered): mainly medium to high strength; can be scratched with difficulty; outer crust can be scraped and plucked with difficulty; contains between 5 and 25 percent penetrating zones of low to medium strength weathered material which can be scraped or gouged

### POOR

- 84. Iron Formation (highly weathered): contains between 25 and 75 percent low strength weathered material which can be scraped or gouged with ease; outer crust containing medium to low strength zones can be scraped and plucked with moderate ease; inner core may have appearance of ochre or pumice

### DELETERIOUS

- 87. Iron Formation (decomposed): low to very low strength; greater than 75 percent of particle consists of low strength weathered material which can be scraped, peeled or gouged with ease

*Note 6: Fissile iron formation should be included in the Greywacke-Argillite-Tuffite-Slate group.*

## OCHRE

### DELETERIOUS

- 60. Ochre: greater than 75 percent of particle consists of ochre

## GYP SITE

### GOOD

- 77. Gypsite (< 10 % gypsum): less than 10 percent of particle consists of gypsum; host rock should be used for particle classification if it is not good aggregate

### POOR

- 78. Gypsite (10-49 % gypsum): contains between 10 and 49 percent gypsum

### DELETERIOUS

- 79. Gypsite (> 49 % gypsum): contains between 49 and 100 percent gypsum

**SEDIMENT: SIBLEY GROUP**

GOOD

80. Sediment: Sibley Group (hard): high strength; very difficult to scratch; scratching does not produce powder

FAIR

83. Sediment: Sibley Group (medium hard): high strength; can be scratched (surficial scratch only; deep scratch not possible); powder produced by scratching

POOR

85. Sediment: Sibley Group (soft): medium strength; can be scratched with ease (deep scratch possible); powders easily; ranges from scraped with difficulty to scraped with ease

DELETERIOUS

88. Sediment: Sibley Group (very soft): low to very low strength; can be scraped and peeled with ease

**QUARTZ**

GOOD

10. Quartz (vein or pegmatitic): does not include quartzite

**TALC**

DELETERIOUS

64. Talc: sectile; greasy to touch

**SULPHIDE**

FAIR

72. Sulphide: particle contains at least 75 percent sulphide minerals such as pyrite, marcasite, and chalcopyrite

**COAL-COKE-CINDER**

DELETERIOUS

31. Coal-Coke-Cinder

**SLAG-GLASS**

DELETERIOUS

92. Slag-Glass (in non-slag aggregate)

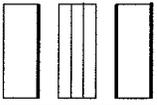
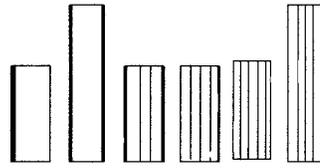
Category	Type	Color	Description
Good	<p>Carbonate (medium hard)</p>  <p>Particles with a thin shale coating on one face; no more than one intraparticle shale seam Equidimensional particles with one to three intraparticle shale seams and elongated particles with one or two intraparticle shale seams Equidimensional particles with a thin shale coating on two faces; no intraparticle shale seams</p>	<p>→ Becoming generally darker</p>	High strength; can be scratched
Fair	<p>Carbonate (slightly shaley)</p>  <p>Particles with a thick shale coating on one major face; no intraparticle shale seams Elongated particles with a thin shale coating on two faces; no intraparticle shale seams Equidimensional particles with a thin shale coating on two faces; one to two intraparticle shale seams Equidimensional particles with a thin shale coating on one face; two to three intraparticle shale seams Equidimensional particles with four intraparticle shale seams Elongated particles with three intraparticle shale seams</p>		Medium strength; can be scratched with ease and scraped with some difficulty; generally shows grey or brown (sometimes greasy) streak when scratched
Poor	<p>Carbonate (shaley)</p>  <p>Particles extensively interbedded with shale or particles with uniform shaley (argillaceous) content throughout</p>		Low strength; can be scraped with ease and peeled with some difficulty; generally shows grey, brown or black (sometimes greasy) streak when scratched
Deleterious	<p>Shale</p>  <p>Particles totally shaley</p>		Low to very low strength; can be scraped and peeled with ease; sometimes greasy to touch

Table 2 Petrographic Classification of Shale-Bearing Carbonate and Shale