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 proposed for use in construction. The test method is subdivided into Parts A, and B. In Part A 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. Part B outlines the procedure for petrographic identification of coarse aggregate derived from either reclaimed asphalt pavement (RAP) or hot mix.

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 Standards

C 294, Standard Descriptive Nomenclature for Constituents of Concrete Aggregates.

C 295, Standard Guide for Petrographic Analysis of Aggregates for Concrete.

2.2 CSA Standards

A23.2-15A, Petrographic examination of aggregates

2.3 MTO Test Methods

LS-282, Method of Test for Quantitative Extraction of Asphalt Cement and Analysis of Extracted Aggregate From Bituminous Paving Mixtures

LS-291, Method of Test for Quantitative Extraction of Asphalt Cement and Mechanical Analysis of Extracted Aggregate From Bituminous Paving Mixtures - Ontario Procedure.

LS-602, Method of Dry Preparation of Aggregates for the Determination of Physical Properties

LS-616, Procedure for the Petrographic Analysis of Fine Aggregate

2.4 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 (SiO_2) or minerals with silica in the crystal structure as silicate (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, 81, 82, 73, 74, 86, 84, 97, 87, 32, and 64.

4. APPARATUS

4.1 HAND LENS: 10x magnification.

4.2 ALNICO MAGNET or PENCIL 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.

PART A

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 out on a tray or other flat working surface.

6.2 If required, the sample shall be visually examined 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 overnight. 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 them easier to recognize.

6.6 The washed sample shall be spread on a flat surface covered with either paper or a 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 (i.e. and possibly requiring a 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 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 and the sum of each of the sub-totals shall equal 100 percent.

7.2 The petrographic number for aggregates used 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 (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 use as granular material.

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 as follows: Compute the percentage of each fraction of the coarse aggregate portion (i.e. retained on the 4.75 mm sieve) of the “as-received” material. Multiply each of these calculated percentages for each of fractions by their respective petrographic numbers for those fractions. The sum of the products is then divided by 100.

7.4.2 For the purpose of calculating the weighted average petrographic number, consider any sizes of the coarse aggregate fractions that were not tested to have the same value as the next larger or smaller size 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 size 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 aggregates.

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 a 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 of '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, then 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 the physical properties into account. The possibility of the aggregate being alkali-reactive in concrete is not considered here.

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).

PART B

11. SAMPLE PREPARATION

11.1 Extract the aggregate from RAP or hot mix as per LS-282 or LS-291, or as specified in the contract documents.

11.2 Enough material should be processed in order to obtain a minimum of 1 kg of clean, dry extracted aggregate retained on the 4.75 mm sieve.

12. PROCEDURE

12.1 All of the coarse aggregate retained on the 4.75 mm sieve shall be examined as a whole.

12.2 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 two hours.

12.3 The washed sample shall be spread out on a tray or other flat working surface.

12.4 Each particle in the sample shall be classified into a rock or material type listed in Table 2.

12.5 In the classification of each particle, features indicated in sections 6.8.1 through 6.8.10 in Part A of this test method may be relevant.

12.6 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 Table 2.

13. CALCULATION

13.1 The percentage of each rock or material type present shall be calculated to the nearest 0.1 percent.

13.2 The percentages of each of the five rock or material type categories present shall be calculated to the nearest 0.1 percent.

14. REPORTING OF RESULTS

14.1 The report of the examination should include the following (reported on Table 2):

14.1.2 The laboratory sample number

14.1.3 The date and the name of the analyst.

14.1.4 If a sample of RAP is being analyzed, the source of the RAP, including the name of contractor, contract number and contract location from where the RAP was milled.

14.1.5 If a sample of hot mix is being analyzed, include the name of contractor, contract number, the contract location from where the hot mix was sampled and the field sample number.

14.1.6 The percentages (to the nearest 0.1 percent) of each rock or material type present.

Ontario

Ministry of Transportation

COARSE AGGREGATE PETROGRAPHIC ANALYSIS - MTO LS-609

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	–			–	–
			TOTALS		

% GOOD _____ X 1 = _____
% FAIR _____ X 3 = _____
% POOR _____ X 6 = _____
% DELETERIOUS _____ X 10 = _____

EST. PERCENT CRUSHED	
EST. PERCENT FLAT AND ELONGATED	

HOT MIX, SURFACE TREATMENT AND CONCRETE P.N.	
CORRECTED GRANULAR P.N.	

Figure 1 MTO Form PH-CC-343

Table 1 Supplementary Rock Type List.

CATEGORY	TYPE	TYPE NUMBER	CORRECTION FOR GRANULAR
GOOD	IRON FORMATION (hard; sl. weath.)	71	-
	GYPSITE (< 10 % gypsum)	77	-
	SEDIMENT: SIBLEY GROUP (hard)	80	-
	FLINT/JASPER	81	-
FAIR	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	-
POOR	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
DELETERIOUS	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	-

Table 2. Petrographic classification of coarse aggregate extracted from RAP or Hot Mix

CONTRACT NO:	**CONTRACT LOCATION:**		**CONTRACTOR:**
SOURCE NAME		**SAMPLE MASS**	
LOCATION		**SAMPLE NO/LAB NO**	
DATE		**ANALYST**	

CATEGORY 1 – DSM #3.05.25 ROCK TYPES (SP12.5 FC2, SP12.5 FC1)	**TYPE NO.**	**MASS**	**%**
DIABASE (hard or medium hard)	08		
DOLOMITIC SANDSTONE (hard or medium hard)	03, 22		
GABBRO (hard)	08		
GNEISS (hard)	04		
GRANITE (hard)	08		
META-ARKOSE (hard or medium hard)	03, 22, 04		
META-GABBRO (hard or medium hard)	08, 04		
TRAPROCK	09		
VOLCANIC (hard or medium hard)	07		
OTHER DSM #3.05.25 ROCK TYPE (please list, describe – see Note 1)	-		
TOTAL CATEGORY 1 AGGREGATE	–		
CATEGORY 2 – CARBONATE ROCK TYPES	**TYPE NO.**	**MASS**	**%**
ALL CARBONATE ROCK TYPES (includes but is not limited to rock types 01, 20, 02, 21, 35, 41, 42, 40, 24, 26, 43, 44, 49, 45, any other rock type where the main mineral component(s) are carbonate minerals	Rock types shown to the left		
TOTAL CATEGORY 2 AGGREGATE	–		
CATEGORY 3 - CONTAMINANTS	**TYPE NO.**	**MASS**	**%**
EARTH	-		
CLAY, CLAY LUMPS	-		
WOOD	-		
CRACK SEALANT	-		
GYPSUM or GYPSUM/PLASTER WALLBOARD	-		
CARDBOARD, PAPER	-		
METALS	-		
STEEL SLAG AND OTHER METAL SLAGS (EXCUDING NICKEL SLAG)	-		
CLAY BRICK OR TILE	-		
GLASS	-		
CERAMICS	-		
AIR-COOLED BLAST FURNACE SLAG, NICKEL SLAG	-		
HYDRAULIC CEMENT CONCRETE	-		
OTHER CONTAMINANTS (PAINT, RUBBER, PLASTIC , ETC.) – Please List			
TOTAL CATEGORY 3 AGGREGATE	–		
CATEGORY 4	**TYPE NO.**	**MASS**	**%**
QUARTZITE (hard) (*SP12.5FC1 only)	05		
TOTAL CATEGORY 4 AGGREGATE			
CATEGORY 5 – OTHER	**TYPE NO.**	**MASS**	**%**
OTHER LITHOLOGIES (please list, describe) – See Note 1)	-		
TOTAL CATEGORY 5 AGGREGATE	–		

% CATEGORY 1 _____
% CATEGORY 2 _____ **TOTALS**
% CATEGORY 3 _____
% CATEGORY 4 _____
% CATEGORY 5

Note: 1) "OTHER DSM #3.05.25 ROCK TYPE" shall only include lithologies which may be added to DSM # 3.05.25 between revisions of this table and SHALL NOT include any FAIR, POOR, DELATERIOUS or brittle particles, regardless of their possible source. These or any other particles that cannot be classified in CATEGORIES 2, 3 or 4 shall be included in "CATEGORY 5 – OTHER".

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 3 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 (≧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

GYPSITE

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)

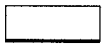
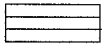
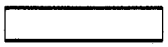
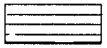
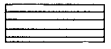
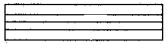
Category	Type	Color	Description
Good	Carbonate (medium hard)  Particles with a thin shale coating on one face; no more than one intraparticle shale seam  Equidimensional particles with one to three intraparticle shale seams and elongated particles with one or two intraparticle shale seams  Equidimensional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

Table 3 Petrographic Classification of Shale-Bearing Carbonate and Shale