CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 66-51

PETROGRAPHY OF LIMESTONE DRILL CORE FROM ST. CONSTANT, QUEBEC

by

JAMES A. SOLES

MINERAL PROCESSING DIVISION

NOTE: THIS REPORT RELATES ESSENTIALLY TO THE SAMPLES AS RECEIVED. THE REPORT AND ANY CORRESPONDENCE CONNECTED THEREWITH SHALL NOT BE USED IN FULL OR IN PART AS PUBLICITY OR ADVERTISING MATTER.

COPY NO. 9

JUNE 20, 1966

Mines Branch Investigation Report IR-66-51

PETROGRAPHY OF LIMESTONE DRILL CORE FROM ST. CONSTANT, QUEBEC

by

James A. Soles*

SUMMARY OF RESULTS

A petrographic examination of two drill cores of shaly limestone from St. Constant, Quebec, showed that less than 40% of the rock in core 66-1-8 and less than 16% in core 66-1-4 had a petrographic number below 140, which is the safe maximum value for aggregate to be used in exposed concrete structures and pavements. The petrographic evaluation indicated that this limestone cannot yield acceptable aggregate without extensive beneficiation additional to that provided by crushing and screening.

* Senior Scientific Officer, Mineral Processing Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa

INTRODUCTION

Cores from two 200-foot holes drilled in shaly limestone of the Trenton formation near St. Constant, Quebec, were examined to evaluate the rock's usefulness as coarse aggregate for concrete. The company which supplied the material, Francon Limited of Montreal, requested that the limestone be evaluated from 'petrographic numbers', obtained by petrographic analysis of the rock in the drill cores.

PROCEDURE

The rock in the drill cores was classified into three general types according to the estimated content of deleterious material, so that the log would indicate the relative soundness of the rock when used as concrete aggregate. Individual sections of different rock types were measured to the nearest centimeter.

Test specimens of each rock type were selected at intervals and etched whith a 50% hydrochloric acid solution to reveal the insoluble constituents, and ensure that the visual estimates of deleterious material in a given section were approximately correct. Microscopic examinations and X-ray diffraction analyses were made on the insoluble fractions when a check on the mineralogy was considered necessary.

The problem of classifying concrete aggregate on the basis of petrography has been studied intensively in the past twenty years (1, 2, 3). Classification of the St. Constant sedimentary rock into specific types was made according to colour and structure, as increasing amounts of clay and shale proportionately darkened the limestone and increased its fissility. Each type has been assigned a 'soundness factor', a figure which indicates the rock's potential quality as aggregate based upon an empirical scale grading from 1. 0 (fully sound, e. g. andesite) to 6. 0 (completely deleterious, e. g. clay). By summing the products of factors and percentages of the different materials in a section of rock, a "petrographic number," or quality rating, was obtained which indicates the durability of the section as a whole. The technique has been described by Bayne and Brownridge (4).

RESULTS

The drill core rock is predominantly fine-grained limestone with shaly interbeds; fossils are ubiquitous, but more common in the shaly strata. A short section of igneous rock, probably a dioritic dyke, is present in one core. The limestone ranges in colour from light grey, in which only minor fine dolomite, quartz and, particularly, dark clay minerals are abundant. The shale bands may grade stratigraphically into dark clayey limestone (Figure 1) or, less commonly, fill interstices between limestone breccia (?) fragments (Figure 2).

The rock classification used is as follows:

Type A. Light to medium grey, hard limestone, containing minor uniformly dispersed quartz, plagioclase, dolomite, and mica clay minerals. Considered as sound rock, resistant to weathering and unreactive with the constituents of cement. Soundness Factor = 1. 5;

Type B. Dark grey, shaly limestone containing noticeable proportions (10 - 25%) of dispersed clay or shaly material, together with dolomite, quartz and feldspar; visibly structureless but often cleavable. The rock is of doubtful quality, and may or may not be sound. Soundness Factor = 3, probably varies from 2 to 5;

Type C. Dark grey to black shale and shaly limestone containing more than 25% acid-insoluble material, usually having a fissile structure. The rock is deleterious, would disintegrate in subaerial weathering conditions and perhaps expand or give a weak bond in concrete. Soundness Factor = 5.

Figures 1 and 2 show typical sections of rock with classifications marked on the boxes.

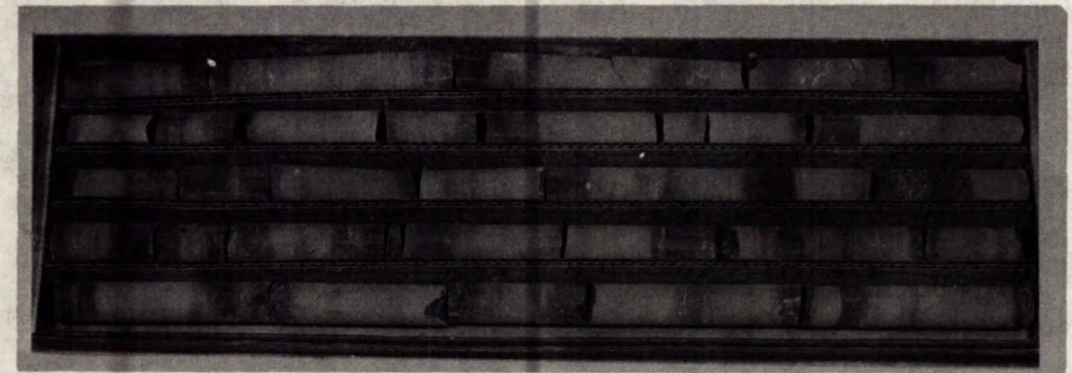

Figure 1. Photograph of drill core from Hole 66-1-8 (100-110 feet), showing dark layers of shale gradational into light-coloured, hard limestone.

Figure 2. Photograph of drill core from Hole 66-1-4, (100-110 feet), showing fragmental limestone (light) and interstitial shaly material.

If the rock is crushed for aggregate, a correction should be applied to compensate for the removal of most (perhaps 75%) of the fissile shale, and the shaly part of the Type B limestone (perhaps 25%). These figures are based upon a minimum discard of 10%, the average discard at a coarse aggregate plant in the Ottawa area; wastage would be greater with rock having a higher shale content. The petrographic numbers for each core interval were recalculated with these figures to assess the improvement that might be obtained from crushing and screening.

The evaluation of the drill cores is summarized in Tables 1 and 2. The numbered columns contain the following data:

Column 1 - core interval
Column 2 - proportion of the core in each section
Column 3 - petrographic description of rock
Column 4 - Type A rock, soundness factor (SF) = 1.2
Column 5 - Type B rock, soundness factor (SF) = 2.5
Column 6 - Type C rock, soundness factor (SF) = 5.0
Column 7 - total shale content of core section, determined by adding Type C rock to 15% of Type B
Column 8 - petrographic number calculated by adding products of the proportions in columns 4, 5 and 6 and the corresponding soundness factor (viz. % A x 1.2 + %B x 2.5 + %C x 5.0)
Column 9 - petrographic number adjusted to compensate for an estimated loss of 10% of rock (shaly material) by crushing and screening.

DISCUSSION AND CONCLUSIONS

Determination of the suitability of a rock for concrete aggregate by petrographic examination alone is risky, therefore it is used mainly to supplement standard physical and chemical tests (5). If the classification into deleterious and innocuous rock types is correct, the prediction of a rock's behaviour is usually reliable; but in some cases apparently safe types of rock may be deleterious, e.g. a competent dolostone near Kingston, Ontario causes serious expansion in concrete (6). Explanation of its behaviour is sought in a rather elegant hypothesis (7) involving dedolomitization and the reaction, with water and the constituents of cement, of clay particles released during the dedolomitization process. Another somewhat revolutionary theory, supported by experimental evidence (8), is that deterioration of many unsound rocks, particularly clayey carbonate rocks, is caused by variation with temperature in the ordering of molecules of a polar liquid (water) adsorbed on the surfaces of minerals adjacent to capillaries.

TABLE 1

Evaluation of Drill Core 66-1-8, St. Constant, Quebec

(1) Core Interval (ft)	(2) Proportion of Core (%)	(3) Petrography	Distribution of Rock Types (%)* Type A SF = 1.2 (4)	Type B SF = 2.5 (5)	Type C SF = 5.0 (6)	(7) Shale Content %	Petrographic Numbers* (8)	(9)
0-6	3.0	Limestone, shaly, fine - grained, fossiliferous; shale layers usually gradational into limestone	90	8	2	3	138	135
6-19	6.5		63	30	7	11	185	156
19-30	5.5		70	24	6	10	174	150
30-40	7.0		68	20	12	15	192	151
44-57	6.5		85	12	3	5	47	134
57-60	1.8	Dioritic rock, fine grained, locally calcitic	100	-	-	-	20	120
60.7-72	5.7	Limestone, layered, shaly like 0-57	67	23	10	13	88	152
72-87	7.5		80	16	4	6	156	140
87-112	12.5		84	14	2	4	146	136
112-130	9.0	Limestone, fragmental, interstitial shale, thin shale seams	78	14	8	10	168	142
130-166	18.0		62	25	13	17	202	158
166-200	17.0	Limestone, like 0-57, partly fragmented	64	23	13	16	199	156
			Weighted Averages of Petrographic Numbers				177	148

* See explanation in text

TABLE 2

Evaluation of Drill Core 66-1-4, St. Constant, Quebec

(1) Core Interval (ft)	(2) Proportion of Core (%)	(3) Petrography	Distribution of Rock Types (%) * Type A SF = 1.2 (4)	Type B SF = 2.5 (5)	Type C SF = 5.0 (6)	(7) Shale Content (%)	Petrographic Numbers* (8)	(9)
0-27	13.5	Limestone, fossiliferous, shaly. Shale layers (2-6) in	71	18	11	14	185	149
27-52	12.5	sharp or gradational contact	67	25	8	12	182	152
52-62	5.0	Like 0-52, thin (1-2") shale layers	79	15	6	8	162	140
62-80	9.0	Like 0-52, more dispersed clay	71	19	10	13	182	149
80-94	7.0	Like 52-62, limestone light grey	78	14	8	10	169	142
94-100	3.0	Limestone, fragmental, interstitial shale	60	29	11	15	199	160
100-113	6.5	Limestone; dark, high clay content	59	23	18	21	218	160
113-130	8.5	Limestone, partly fragmental, light grey; shale layers (0.5 - 2")	70	15	15	17	196	149
130-137	3.5	Shale, thick gradational layers	54	27	19	23	227	165
137-147	5.0	Like 113-130	69	13	18	20	205	147
147-158	5.5	Shale, thin gradational layers	77	10	13	15	182	143
158-175	8.5	Like 113-130	76	14	12	14	186	148
175-184	4.5	Shale, thick layers grading into med. grey clayey limestone	48	31	21	26	239	171
184-198	7.0	Mostly like 113-130, rare calcite veins	76	18	7	10	171	146
198-200	1.0	Like 130-137	66	24	10	14	189	154
			Weighted Averages of Petrographic Numbers				190	150

* See explanation in text

The fissile, shaly part of the St. Constant limestone would probably be deleterious in concrete, and most of it (Type C and part of B) would have to be removed. The hard, light-coloured limestone (Type A) would probably be sound, although an increasing content of dispersed clay would likely decrease its stability. Intermediate rock (Type B) is difficult to assess because the limit of dispersed clay for acceptance has not been determined. Unlike Type C, it is relatively hard and resistant to crushing, and most of it would be retained as coarse aggregate; however, if it is reactive with cement constituents, or otherwise deleterious, it may damage concrete in unfavourable environments. All rock classified as Type B should be suspected as deleterious unless it is proved to be innocuous.

Petrographic numbers in Column 9 of Tables 1 and 2 indicate the relative soundness of rock in individual sections of the cores after improvement by crushing and screening (see page 3). A petrographic number of 140, considered by the Ontario Department of Highways as the safe maximum for aggregate in concrete structures and pavements (4, p. 96), may be used for comparison.

According to this method of evaluation most of the rock represented by the drill cores is unsuitable for concrete aggregate. Only rare sections, usually less than 20 feet thick, have petrographic numbers under 140. Less than 40% of 66-1-8, and less than 16% of 66-1-4 is suitable for aggregate without beneficiation additional to that assumed to be obtainable by crushing and screening.

REFERENCES

1. R. Rhoades and R. C. Mielenz, "Petrographic and Mineralogic Characteristics of Aggregates", In: "Symposium on Mineral Aggregates", ASTM, Spec. Tech. Publ. No. 83, 20-48 (1948)

2. E. G. Swenson and V. Chaly, "Basis for Classifying Deleterious Characteristics of Concrete Aggregate Materials", Journ. Amer. Concrete Inst., 27 (9),987-1002 (1956)

3. R. C. Mielenz, "Petrographic Examination", In: "Significance of Tests and Properties of Concrete and Concrete Aggregates", ASTM Spec. Tech. Publ. No. 169, 253-273 (1955)

4. R. L. Bayne and F. C. Brownridge, "Petrographic Analysis for Determining Quality of Coarse Aggregates", Roads and Engineering Construction, 93 (11), 90-98 (1955)

5. Anon. "Concrete and Mineral Aggregates", ASTM Standards, Part 10, 516 pages (1965)

6. E. G. Swenson and J. E. Gillott, "Characteristics of Kingston Carbonate Rock Reaction", In: "Concrete Quality Control, Aggregate Characteristics, and the Cement-Aggregate Reaction", Highway Research Board, Bull. 275, 18-31 (1960). (NAS-NRC Publication 1167)

7. J. E. Gillott, "Mechanism and Kinetics of Expansion of the Alkali-Carbonate Rock Reaction", Canadian Journal of Earth Sciences, 1 (2), 121-145 (1964)

8. J. R. Dunn and P. P. Hudec, "The Influence of Clays on Water and Ice in Rock Pores, Part 2", New York State Department of Public Works, Bureau of Physical Research, Report RR 65-5, 149 pages (1965). (Rensselaer Polytechnic Institute, Department of Geology, Contribution 65-8)