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THE PETROGRAPHY OF SEDIMENTARY ROCKS FROM THE TORQUAY AREA, VICTORIA

by

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Following are descriptions of certain rocks collected by Dr. H.G. Raggatt in the Torquay - Airey's Inlet area, Victoria. As the rocks are isolated specimens, and no general conclusions applicable to the group as a whole have been drawn, the preparation of a summary is not warranted.

1. White Rock from near top of Addiscot Member, collected from western end of Demon's Bluff cliffs, east side of Anglesea River.

Most of this specimen is very fine-grained - average grainsize 0.005 to 0.0025 mm. It contains a few quartz grains of average diameter 0.1 mm., and also a little clay. Its specific gravity is 2.58. Excepting the clay and quartz, the rock is soluble in hot sulphuric acid; from the solution aluminium hydroxide was precipitated by adding ammonium hydroxide. The greater part of the rock is soluble in caustic soda solution also. Water is given off on heating in the closed tube. The refractive index of the soluble material is about 1.557.

These tests indicate that the soluble mineral is gibbsite. The low double refraction (too low for gibbsite), as observed in thin section, is due to the extremely fine grain size of the mineral. Gibbsite has a specific gravity of 2.35±; the figure 2.58 is somewhat high, but would probably be accounted for by the impurities.

The mottled yellowish grey (5Y7/2) and dark grey (N3) substance, which borders and marginally penetrates the gibbsite as veinlets, was also examined, and was found to consist essentially of montmorillonite containing irregularly distributed angular grains of quartz (average grainsize 0.1 mm), which may occupy up to 35 per cent by volume of the rock. Minor constituents are fragments of felsite or chert, black iron ore, leucoxene, zircon and rutile. The montmorillonite is patchily and lightly stained by limonite, and generally has aggregate polarization.

Refractive index measurements, which formed the basis of the determination of the montmorillonite, yielded the following results:-

i. Yellowish grey material 1.515 ±

ii. Dark grey material 1.500 ±

These figures lie within the ranges quoted for different types of montmorillonite.

2. Bright green material (glauconite (?)) from near the top of the Jan Juc Formation, near Bird Rock.

In the hand specimen, this material is coloured dusky green (5G3/2), and has a somewhat velvety appearance. Nests of minute octahedra of pyrite are present in small hollows and open cracks and, to a lesser extent, in the body of the rock.

Measurements with immersion media showed that the mean refractive index of the green mineral is approximately 1.560; this figure is very much below the lower limit of the range usually stated for the mean index of glauconite, viz. 1.609 to 1.643, and is close to those recorded by Dallwitz (1948, p.1) for glauconite from Maslin's Beach, South Australia; it is also lower than the actual limits (1.575 to 1.602) found by Glover

(1950, p.15), in glauconite from rocks of the Torquay-Airey's Inlet area. These discrepancies suggest that chemical and optical work should be done to establish the full ranges of composition and optical properties of the group of minerals broadly classed as glauconite; such work may also throw light on the origin of different types of glauconite, and on varying conditions of sedimentation and diagenesis which may be responsible for the differences.

In thin section the glauconite is coloured bright yellow green, and has embedded in it scattered quartz grains, shell fragments and foraminiferal tests, and rare pyrite, all of which make up not more than 5 per cent of the whole rock. The chambers of the foraminifera are filled with glauconite. Some of the glauconite is coarse-grained; one area which extinguishes as a unit measures 2.5 mm x 2.5 mm.

Part of the specimen could not be successfully sectioned. On crushing, this was found to consist of quartz, shell fragments, glauconite, foraminiferal tests partly or wholly filled with glauconite, and claystone.

Only an exceedingly small part of the glauconite in the thin section examined is enclosed in the tests of organisms (foraminifera). As no clay remains in the section, it is probable that glauconite has replaced the clay en masse. Particles of clay observed in crushed material from other parts of the specimen (see above) have, presumably, escaped the extensive glauconitization which has taken place in the sample as a whole.

It is, therefore, concluded that the bulk of the glauconite in this specimen represents an extreme case of Glover's (loc.cit., p.16) second class, viz., "glauconite with indefinite boundaries which grade imperceptibly into the surrounding argillaceous material".

3. Concretions in top of Jan Juc Formation at Bird Rock.

The sample is a friable, clastic rock, consiting of two distinct portions. One part, which may be considered as the matrix of the other, is coloured very light olive green (5Y7/1), and consists microscopically of shell fragments, shells, quartz grains, and glauconite. The other part (the "concretions") is composed of light olive grey (5Y6/1) claystone containing shell fragments, shells, and a high percentage of somewhat irregularly distributed glauconite; small scattered crystals and grains of pyrite can be identified with the aid of a lens. Where the claystone carries no glauconite, it has conspicuous shrinkage cracks. The glauconite varies in colour between greyish-green (10 GY5/2) and dusky yellow green (5GY5/2).

The mutual relationships of the two parts of this rock can not be conclusively determined from the specimens at hand. However, it appears probable that the more argillaceous glauconite - rich masses have been laid down in the troughs of water-current ripple marks. Conditions where this could happen are consistent with those under which much glauconite is now thought to have formed (Lochman, 1949, p.56; Imlay, 1949, pp.90-91). A concretionary mode of origin for the more highly glauconitic and quite distinct type of rock, seems to be impossible.

The "matrix" is composed of shell fragments, clay which is mostly bonded by calcite, quartz grains, glauconite, and foraminiferal tests. Microscopically, it is impossible to estimate, even approximately, the ratio of carbonate to clay; however, it is clear that the percentage of clay is very much less than that of carbonate. The quartz grains are angular, and have an average size of 0.07 mm; they make up 15 to 20 per cent of the rock. Glauconite is present to the extent of about

3 per cent. Most of it belongs to Glover's first class - that is, it is or was included in tests of organisms, particularly gastropods, foraminifera, and parts of echinoid plates. In some cases only the outer chambers of foraminifera carry glauconite; however, most of the foraminiferal tests are free from this mineral. Only a few of the broken echinoid plates contain glauconite, and mostly only a group of pores in any one plate fragment is filled with glauconite. Some of the glauconite falls into Glover's second class; generally, this glauconite takes the form of oval to semi-oval and irregular masses with sharp boundaries, and appears not to have been enclosed within tests of organism at any time. In addition, a few oval grains ((?) coprolitic mud) show only incipient glauconitization, a stage in which a strong overall tinge of green has been imparted to the originally brown grain. Finally, a little of the glauconite has "indefinite boundaries" which appear to grade imperceptibly into the surrounding argillaceous and calcareous material (Glover, loc.cit.,p.16).

Accessory minerals - black iron ore, pyrite and zircon - are very rare in this part of the rock.

The "matrix" is a clayey, sandy, and shelly, calcareous calcarenite, carrying a small percentage of glauconite.

The glauconite-rich rock associated with that described above, differs from it in the following ways:-

i. Quartz is less plentiful - it makes up 5 to 7 per cent of the rock as against 15 to 20 per cent in the "matrix".

ii. Clay is much more plentiful, and a high proportion of it is not bonded by calcite.

iii. Glauconite is an important constituent. It is irregularly distributed and makes up about 15 per cent of the rock.

Thus, the major constituents of this portion are calcite (as broken and unbroken shells), clay, glauconite, and quartz, in decreasing order of abundance. Accessory minerals are quite rare, and consist of pyrite, black iron ore, probable marcasite, and fine flakes of muscovite. The rock is a clayey, glauconitic, and silty, calcareous calcarenite, containing numerous shells and shell fragments.

Recognisable shell fragments and complete skeletons comprise lamellibranchs, foraminifera, gastropods, echinoids (parts of plates and spines), and bryozoa. Perforated or ornamented spherules or cylinders of calcite, representing organisms or parts of organisms, are conspicuous in some places, but occupy probably less than 0.1 per cent by volume of the rock.

The pyrite, which occurs as irregular grains, cubes and octahedra, is generally enclosed in or closely associated with glauconite; it is commonly bordered by black iron ore, separate grains of which are also scattered through the rock. The (?) marcasite is found as aggregates or strings of minute grains embedded in the clayey, calcareous cement, and is accompanied by varying amounts of black iron ore.

Glauconite occurs in all of the ways previously described for the "matrix", but dominantly as sharp-bordered oval and irregular grains, as distinct from in-fillings of shells. It appears to have been derived from clay or from

coprolitic pellets, and its abundance is a reflection of the abundance of clay in this portion of the rock, as compared with the "matrix". The predominance of this type of glauconite lends support to the idea that mud, and not biotite, is commonly the progenitor of this mineral.

A few of the masses of glauconite simply grade outwards by decrease of that mineral into the surrounding clay, and in other cases clay is only lightly impregnated with glauconite; both conditions suggest derivation directly from clay.

Many of the probable coprolitic pellets now converted to glauconite contain minute grains of quartz (see Figs. 4,5 and 7, Takahashi and Yagi, 1929, p.845).

The glauconite which occurs in tests of organisms does not completely fill the cavities in every case, but appears to have shunk away from the walls; this condition is particularly conspicuous where the mineral is contained in the openings of a bryozoal skeleton. In some places the tests are partially broken and/or dissolved, but the original shapes of the enclosed glauconite masses is retained.

All the glauconite shows aggregated polarization. Its refractive indices are again lower than those usually recorded, and vary from one mass to another. Most aggregates have a R.I. of about 1.565, but some fall below 1.560, and others range above 1.570. This apparent lack of constancy in composition would make definitive chemical and optical work impossible, but would still allow significant generalised data to be obtained.

4. <u>Specimen from Great Ocean Road, ¼ mile N.W. of Urquhart's Bluff</u>.

A medium-grained, clastic, current-bedded rock, whose colour varies according to the limonite content. The predominant colours are shades of dark yellowish orange (10YR 5.5/6 to 10YR6.5/6). Other bands grade with increase of limonite into dark orange-brown (10YR4/6); a narrow limonite-poor, pale greyish yellow (5Y8.5/4) band is also present. A clayey filling found in cracks is coloured light brown (5YR5/4).

Microscopically, the rock is seen to consist mainly of quartz and limonitic clay.

The quartz grains are sub-angular to angular, and they fall into two groups according to grain size. The coarser grains average 0.08 mm, and the finer 0.025 mm. Only rarely are the coarser quartz grains in contact with one another - they are commonly separated by a matrix consisting of fine quartz grains and/or clay impregnated with limonite.

Other components observed in thin section are rounded fragments of probable shale, ovoid and semi-ovoid pellets (possibly coprolitic in part, and possibly also representing leached and altered glauconite), rare black iron ore, leucoxene, muscovite, acid plagioclase, microcline, a fragment or two of possible spherulitic acid volcanic rock, and very rare zircon and glauconite. In a concentrate obtained by panning the following minerals, in order of abundance, were present - ilmenite, zircon, leucoxene, tourmaline, rutile, sphene, magnetite, glauconite, blue corundum, and probable celestite or barytes. Substances traceable to a basic volcanic origin are absent as far as can be determined.

decreasing

The quartz grains, including those of the matrix, are fairly evenly distributed, but the clayey limonitic matrix, shale fragments, and ovoid pellets tend to be more concentrated in ill-

defined and irregular bands and clots. The estimated percentage composition of the rock is as follows - quartz of fine sand grade 60; quartz of silt grade 18; limonite-stained clay 15; and shale fragments, ovoid pellets, and accessory minerals 7. The rock is a limonitic-clayey, silty fine sandstone (limonitic-clayey, silty fine quartz greywacke).

(In describing the colour of this rock it was again found necessary to guess at colours and coin names and symbols, which do not appear on the colour chart, viz., 10YR5.5/6, 10YR4/6, 5~~10~~Y8.5/4; this last symbol may be impossible, as the highest figure for lightness is 8, but the colour referred to is decidedly lighter than 5Y8/4).

5. Specimen from Great Ocean Road, ½ mile west of Painkalac Creek (Airey's River) Bridge - EV/3.

This is a friable, mottled rock with the texture of a claystone; it is externally and internally traversed by a network of shrinkage cracks. The principal colours giving rise to the mottling are moderate red (5R4.5/4) and dark red (5R4/4). Another prominent colour is pale yellowish grey (5Y7.5/2), but this appears mainly in one band; scattered pale greyish yellow (5Y8.5/4) flecks are also present.

Microscopically, the rock is found to consist of a fine-grained, dark yellowish brown (10YR4.5/2) matrix in which are embedded very irregularly shaped fragments of devitrified glass and angular fragments of quartz.

The matrix is volcanic ash. It is invariably darker than average in a zone about 0.025 mm., wide round the borders of the glass fragments. Variation in concentration of clots and disseminated particles of haematite in the matrix imparts the mottling to the hand specimen.

The outlines of the glass fragments are extremely ragged, as would be expected in a tuff. Their average size is about 0.3 mm., and the largest measures 1.25 mm. Quartz grains are included in some of the fragments.

In the slide at hand the dimensions of the quartz grains varies between 1.75 mm. and 0.01 mm., but most are about 0.3 mm. across. Shattering in a few grains confirms the suggested explosive volcanic action. Felspar may have been present, but, if so, it is now so much altered that it can no longer be distinguished.

Single grains each of zircon and tourmaline were the only accessories noted.

The estimated percentages of the major constituents are - haematite-stained ash 67, devitrified glass 19, and quartz 14.

The rock is an acid ashstone containing fragments of devitrified glass and of quartz.

6. Demon's Bluff Formation.

The specimen is a fine-grained, clastic, friable, and coarsely mottled rock whose colouring varies between dusky yellowish brown (10YR2/2) and light yellowish brown (10YR5/2). Bedding is not prominent; where visible it is in the form of discontinuous bands of varying colour from 1 mm. to about 1 cm., thick, and showing evidence of current action. Only scattered flakes of muscovite can be conclusively identified with the aid of a lens.

On strong heating the rock is bleached and gives off an odour of burning coal.

For microscopic examination the darkest part of the rock has been sectioned.

Quartz is the dominant mineral. Very few of the grains are rounded; most are angular, some are splintery, and a few subangular. Their grainsize is fairly uniform, and averages 0.05 mm.

The quartz grains are set in a matrix of carbonaceous clay. This matrix may occur interstitially between the quartz grains or as irregular clots and bands containing a few grains of quartz, sericite, chlorite, marcasite, and felsitic igneous rock or chert; the size of these included grains ranges from 0.05 mm. down to 0.005 mm. or less. In colour the carbonaceous clay varies between very dark orange brown (10YR3/6) and dusky orange brown (10YR2/6), depending on the degree of concentration of carbonaceous matter. The clay has probably been derived from a vegetable slime. Small irregular bands and clots of brown coal represent strong concentrations of carbonaceous matter.

Unevenly distributed through the rock are fragments of a chloritic mineral, possibly altered and leached chamosite, occurring in grains of about the same size of those of quartz. This mineral is length slow and biaxial negative with low optic axial angle; it has micaceous cleavage and straight extinction, may be faintly pleochroic, and has a double refraction of approximately 0.005. In colour it varies between pale greyish yellow (5Y8.5/4) and dusky yellow (5Y6/4); this variation may be partly due to staining by organic material. Some grains show aggregate polarization.

Minor constituents, in roughly decreasing order of abundance, are chert or fragments of felsite, marcasite, muscovite, leucoxene, felspar (acid plagioclase, orthoclase, and microcline), brown and green tourmaline, zircon, very rare glauconite, ilmenite, monazite, and (?) cassiterite. The last three minerals were found in the residue obtained by panning.

The sectioned portion of the rock consists of an estimated 50 per cent quartz, 38 per cent clayey and carbonaceous cement, 5 per cent chlorite, 2 per cent (?) chert, and 5 per cent other constituents, and is a <u>clayey, carbonanceous greywacke-siltstone</u>, or, more specifically, a <u>carbonaceous quartz-clay siltstone</u>.

(It is to be noted that, in describing the colour of the matrix of this rock, the colour names very dark orange brown and dusky orange brown are used. These colours do not appear on the colour chart, and so the above colours and their names were chosen more or less by guesswork. The colour pale greyish yellow for the chloritic mineral was arrived at in a similar way).

7. <u>Addiscot Formation</u>.

The sample is a friable, non-bedded, medium-grained clastic rock, in which only scattered flakes or muscovite can be microscopically identified. In one area small dark clots, apparently rich in carbonaceous material, are visible. The colour of the rock is very pale yellowish brown (10YR7/2).

Microscopically the rock is seen to consist essentially of even-grained quartz grains in a matrix of clay.

The quartz grains are angular to sub-angular, and a few are splintery. Their average grainsize is 0.07 mm.

The clay is unevenly distributed and is varyingly, though lightly, stained by limonite.

Other constituents of the rock are rounded fragments of felsite or chert, leucoxene, ilmenite, brown and green tourmaline, chlorite similar to that in the Demon's Bluff Formation, muscovite, felspar (acid plagioclase, orthoclase, and microcline), zircon, rare granular limonite, and very rare epidote and probable glauconite. In a dish concentrate rutile and a little monazite were found in addition; this concentrate also revealed some perfect, water-clear, doubly-terminated crystals of zircon, which may have formed during diagenesis. No carbonate was noted in the slide, but slight effervescence took place when the rock was attacked with cold dilute HCl, and further effervescence occurred in hot concentrated HCl.

The rock consists of about 55 per cent quartz, 38 per cent limonite-stained clay, and 7 per cent other minerals, and is a very fine quartz-clay greywacke.

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