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DISSOLUTION BY PORE FLUIDS AND THE INTRODUCTION OF A VARIETY OF MINERALS AS NEW MATRICES IN SEDIMENTS FROM CURDIMURKA

GEOLOGICAL SURVEY

by

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DISSOLUTION BY PORE FLUIDS AND THE INTRODUCTION OF A VARIETY OF MINERALS AS NEW MATRICES IN SEDIMENTS FROM CURDIMURKA

ABSTRACT

Arenaceous sediments from Curdimurka have been subject to strong dissolution by pore fluids at a time after lithification. The resultant high porosity has either remained open or has been filled or partially filled by dolomite, a mixed sulphate material and a mica which subsequently altered to a clay. The sulphate may contain enough potassium to be of economic interest.

INTRODUCTION

Seven thin sections cut from five rock specimens were received for petrographic description from Graham Krieg of the Regional Geology Branch.

PETROGRAPHY

Specimen 6338 RS 50, TS C43713A, Bop/9/112/6

Rock name Dolomitised greywacke with black dendrites.

Hand specimen

A poorly defined banding imparts a weakly bedded fabric to the rock. The banding is fine at one level and coarse at another and is manifested by varied concentrations of silicate grains. The matrix of the rock consists of a pale yellow carbonate which is coated with a pale orange, powdery limonite on the weathered surface. On this evidence the carbonate carries a low to moderate content of iron and is probably in the dolomite-ankerite range of composition.

A second fabric is imposed by small dendrites of an opaque, black material, probably manganese oxide, which are preferentially aligned in a direction approximately perpendicular to the bedding. The manganese has penetrated a system of microfractures, the orientation of which is demonstrated by two somewhat larger fractures. These are accentuated by penetration of the epoxy resin impregnating the specimen and by a weak marginal alteration in the rock.

Thin section

Textural evidence indicates that the sediment is a dolomitised greywacke.

The detrital component includes abundant quartz, plagioclase, lithic fragments and chlorite with minor muscovite and biotite and a little microcline, hornblende, sphene, apatite and zircon. The feldspars are unaltered but the micas are partially altered to chlorite and clay minerals. The abundant chlorite is probably an alteration product of both amphibole and mica.

The shape of the detrital grains varies between elongated and angular splinters and sub-spherical particles. However, grain shape is the result more of chemical corrosion than of sedimentary abrasion. Grain margins are frequently embayed and fractures are filled with carbonate. When minerals with a prominent cleavage have been split along a simple plane, the two fragments often remain in optical continuity although wedged apart. The introduction of carbonate has, on this evidence, taken place in a physical state very closely approaching the solid.

The carbonate is a dolomite but, on the evidence of the hand specimen, contains an appreciable ankerite component. It occurs as a closely interlocked, interstitial mosaic of grains which are substantially coarser than the silicate detritus and which are frequently fibrous in structure. In so far as these coarse grains may be referred to as a matrix, the sediment is matrix supported. The carbonate has been introduced not only by replacement of the original matrix but probably also of the finer grains of the sedimentary framework.

The opaque manganese oxide has been introduced by replacement, largely of the carbonate but to a minor extent of the silicates. Preferred orientation of the irregular patches is not as prominent on a magnified scale as in hand specimen but a spatial association with open fractures is evident, but not exclusive.

Comment

The detritus of the sediment exhibits evidence of rapid sedimentation and lithification of the products of erosion of a terrain composed dominantly of intermediate igneous rocks. Replacement of a matrix probably consisting of clay and chlorite by dolomite occurred after diagenesis, possible after a long time lapse.

Specimen 6338 RS 50, TS C43713B, Bop9/112/6

Rock name Dolomitised greywacke

Hand specimen

The specimen appears to be totally different from RS50A in hand specimen and the close relationship between the two rocks is only apparent in thin section. The hand specimen is brown with white patches but the weathered surface is distinct from the under surface. On the latter the white patches tend to merge into irregular masses with small, interstitial patches of limonite. On the weathered surface the white patches are round with a radiating, fibrous structure and stand above the red brown limonite surface which is more widespread than on the lower surface.

No dendritic manganese oxide is apparent.

Thin section

The replacemnt of detrital grains has proceeded further in this specimen than in RS50A, partly because of greater replacement by dolomite but partly because of substantial replacement by limonite. The original sediment was probably the same as RS50A.

The detrital grains are small and corroded and dominated by quartz, mainly because plagioclase and the other species of framework grains have been preferentially replaced. A few plagioclase, chlorite, mica and chlorite grains and lithic fragments remain. Silicates are even sparser towards the weathered surface.

The dolomite is much more strongly fibrous than in RS50A, in which some fibrous structures were evident, and tends to be amalgamated into subrounded masses composed of smaller subrounded domains. Vague cruciform extinction bands indicate between crossed polarisers that a fibrous recrystallisation is developing within the larger masses. Towards the weathered surface the recrystallisation is complete and rosettes with well marked radiating, fibrous structure and a spherical outline are even larger in size.

The opaque to translucent brown limonite forms interstitial patches to the carbonate. In the interior of the specimen they are less abundant than the dolomite but near the weathered surface limonitic replacement is in some places more abundant than the rosettes of carbonate.

Comment

The evidence that specimen RS50B is a more altered form of RS50A raises the possibility that all the dolomitisation of the greywacke has occurred as a surface or near-surface calcretisation. Progressive alteration may be followed from the interstitial carbonate of RS50A through the coarser, more abundant and more fibrous dolomite of the main part of RS50B, where limonite is also a replacement, possibly lateritic, product to the weathered surface of RS50B in which fibrous carbonate and limonite have recrystallised and amalgamated into large masses and have almost completely replaced the original greywacke.

Specimen 6338 RS 54, TS C43815

Rock name Dolomitic quartzite

Hand specimen No specimen available.

Thin section

The sediment was, from the time of deposition, markedly different from RS50 and subsequent dolomitisation has been very minor in comparison with the latter specimen.

Mineralogically the sediment consisted originally almost exclusively of quartz. The framework is still composed dominantly of quartz grains with minor lithic fragments of quartzite and of recrystallised colloidal silica. If there were originally any matrix, it was not abundant enough to fill the interestitial spaces because authigenic overgrowths on many grains exhibit well shaped crystal faces which could only have developed in open spaces flushed with pore solutions. Quartz grains are in contact only at isolated points on their surfaces and originally the rock must have been a highly porous sedimentary quartzite.

The only other minerals involved in the framework are tourmaline, which occurs as very rare grains, and zircon and muscovite which occur as rare inclusions in quartz.

The shape of the quartz grains has been slightly modified by reaction with introduced dolomite. The grain margins are embayed but the overall shape remains as that acquired during sedimentation, apart from authigenic overgrowths. Most grains are subrounded but a range of shapes between spherical and elongated is evident. The sediment is still largely framework supported. Grain size sorting is moderately good.

The interstitial dolomite is almost certainly similar in origin to that of specimen RS50. It is weakly fibrous in places and has been built up in several episodes of precipitation. This is marked by a zonal structure in which weakly crenulated growth layers are distinguished by the density of fine, opaque inclusions. The inclusions may be composed of iron oxide and may represent the iron from an ankerite carbonate which was observed in specimen RS50 as limonite.

In places the dolomite occurs as separate grains but it consists mainly of a weakly fibrous, poorly crystalline mass which completely fills the interstitial spaces. The carbonate is not in equilibrium with the quartz and has replaced the silica in embayments of the margins of quartz grains. Some grains are more strongly corroded than others and a few have been diminished in size sufficiently to be completely surrounded by the dolomite. The major part of the sediment remains framework supported and the amount of carbonate replacement is minimal in comparison with that of the greywackes of RS50, A and B.

Comment

Specimen RS54 is distinct in two respects from RS50. The original sediment was a coarse, clean, well sorted, mature quartz sandstone with a very high porosity instead of a greywacke. The dolomitisation which has strongly modified the composition and texture of RS50 has affected RS54 only to the extent of filling the porosity and replacing to a generally minor extent the surface of the quartz grains. Whether these two factors are related or whether the sediment was above the water table during most of the dolomitisation can more effectively be determined by field relationships than by petrographic examination.

Specimen 6438 RS 375, TS C43714A, Wang 14/107/0.84
Rock name Bedded quartz sandstone with iron staining
Hand specimen

The specimen is a very friable, coarse grained sandstone which is stained by limonite and contains thin beds of both coarser and finer grain size. Two thin bands of lighter colour are formed by fine grain size, and consequent lower porosity, which hampered the penetration of the fabric by solutions depositing limonite. The coarser grained bands contain very coarse grained, rounded clasts of quartz and silicious lithic fragments. Complete penetration of the rock by impregnating resin indicates a high, connected porosity.

Thin section

By far the most dominant clastic component is monocrystalline quartz. Lithic fragments of quartzite and fine, colloidal silica are common and a few grains of plagioclase and mica are present.

Sorting is moderate and grain shapes vary from spherical to
7 angular with most grains in subrounded to subangular forms. Embayment of the outlines and overall corrosion of grains is widespread and in some grains is quite substantial. Authigenic overgrowths are visible on some but not many grains and may have been largely removed. Fine detrital grains and some patches of clay and mica fill the interstices at a few points and are particularly prominent in the finer grained bands. It appears likely that the abundant porosity is secondary in origin.

Most of the sediment is free of matrix, as just noted, and what matrix remains consists of fine quartz, clay and mica. However, the walls of all the cavities of the extensive system of porosity are coated with a red-brown material. The main component of this is clearly an amorphous limonite but the material is weakly birefringent and a crystalline or at least cryptocrystalline mineral is involved. A few recognisable flakes of fine grained and poorly crystalline muscovite are identifiable in the interstitial spaces and it is possible that a clay derived from sericitic mica may form part of the lining of cavity walls. Optical determination is not definitive in this situation and non-optical methods are recommended if identification is critical. One interesting possibility is that the brown material may contain fine, fibrous jarosite with a preferred orientation perpendicular to the cavity walls, or another sulphate with relatively iron-rich composition and a marked birefringence.

Comment

The sediment is somewhat similar to specimen 6338 RS 54 but dolomite has not invaded the porosity of the rock. Solutions passing through have deposited enough limonite to colour the rock and an unknown birefringent mineral. The friability and high porosity are the result of the dissolution of the original matrix and cement by pore solutions.

Specimen 6438 RS 375, TS C43714B, Wang 14/107/0.84

Rock name Sandstone with sulphate matrix.

Hand specimen

The rock is a pale brown, medium grained quartz sandstone with a massive to very weakly bedded structure and hackly weathering. From its roughly tabular form the specimen was probably bounded originally by joint faces but no such structures are visible and the originally plane surfaces have been modified into hollows and peaks by erosion in which chemical corrosion has dominated physical abrasion.

On one erosion face, on a broken face and on the sawn surface of the specimen the rock reflects light when held at a particular angle to the source. Viewed through a hand lens the reflected light is seen to be derived from the matrix while framework grains remain dull. Material removed with a needle from a glassy patch of matrix contained both fibrous and platy crystalline minerals with a very low hardness.

Thin section

The framework of the sediment consists largely of quartz grains but includes a wide variety of minor constituents such as plagioclase, microcline, tourmaline, zircon and muscovite. The unstable minerals remain unaltered but are not abundant enough to justify the name greywacke for the rock.

Grain shapes are very varied but owe their nature more to corrosive processes than to physical abrasion during sedimentation. Some grains remain in contact but much of the sediment is matrix supported.

The matrix consists of a brown, fibrous to platy material with very varied birefringence and probably a range of compositions. Material extracted with a needle and examined in refractive index oils gave exactly the refractive indices of gypsum and it may be assumed that fine grained material in the matrix with low birefringence probably is gypsum. However, the major part of the matrix exhibits too high birefringence for gypsum. Large areas of matrix are seen in thin section to be in optical continuity and the continuous reflection of whole faces of the hand specimen at one angle to the light source indicates that the matrix consists of minerals which are structurally and compositionally related very closely. The brown colour and moderately high birefringence of most of the matrix suggests that polyhalite may be a major constituent but other sulphates may also be present. Occasionally the margins of quartz grains are coated with fibrous sulphates with high birefringence which may be anhydrite or jarosite. This is additional evidence to suggest that the coating of framework grains which is seen to be partially concealed by limonite in RS375A may also be a sulphate of this type.

Comment

Optical identification of fine, fibrous and platy grains is not entirely definitive and, in view of the interest in sources of potassium for agricultural use, it is recommended that non-optical methods be employed to confirm the presence of sulphates such as polyhalite, $K_2 Mg Ca_2 (SO_4)_4 2H_2O$, and to seek possible alunite, $K Al_3 (OH)_6 (SO_4)_2$. If the matrix sulphate occurs over a wide area and contains significant potassium, the area may be of considerable economic importance.

Apart from the economic aspect, the rock is of interest in indicating that the processes of sulphate introduction are similar to those of calcretisation or dolomitisation. The rock is a developing gypcrete and the possibility that it may contain potassium is significant for other gypcretes in the area.

Specimen 6438 RS 376, TS C43715, Wang 15/084/30

Rock name Kaolinitic quartz sandstone

Hand specimen

The specimen is a very friable, weakly bedded quartz sandstone. Even in hand specimen, grain size sorting is visibly poor. Enough kaolinite is present in the matrix to leave soft, white smears on the fingers after rubbing the crumbly specimen.

Thin section

The framework of the sediment is almost exclusively composed of silica. Quartz is by far the dominant constituent but minor lithic fragments of both coarse grained quartzites and a chalcedonic silica are also present. The only grains not composed of silica are a few micaceous and argillaceous lithic fragments and rare grains of tourmaline.

The texture of the rock varies from porous to matrix-rich and the uptake of impregnating resin is corresponding variable. Porosity is secondary and consequent upon the dissolution not only of a matrix which consisted of clay with fine grained quartz clasts but also of coarser framework grains of quartz. Where dissolution has not occurred the sediment is largely matrix supported but in patches of strong secondary porosity the sediment is unsupported. The kaolinitic matrix is structurally weak and this, together with the lack of support in areas of dissolution, accounts for the extreme friability of the rock. There is some indication in the hand specimen that the distribution of porosity is controlled by bedding but there is little support for this on the scale of the thin section. High porosity is patchy and appears random in distribution.

The poor sorting seen in hand specimen is confirmed in thin section. There is a tendency for coarse grains to be well rounded while fine grains are angular. Some of the coarse grains are bordered by a rim of authigenic quartz but this may have been acquired in an earlier sediment. The strong diversity in grain size and shape suggests that the sediment has probably been recycled, possibly several times. The clay of the matrix was probably original to the rock and is an extreme product of the poor sorting rather than of the decomposition of a more resistant mineral.

Comment

The rock is a rapidly deposited, poorly sorted quartz sediment with a kaolinitic matrix. Many grains are well rounded but probably originated in earlier sediments. The sediment has been subjected to strong dissolution which has produced a patchy but widespread and connected porosity and has weakened the fabric to the point of extreme friability.

Specimen 6438 RS 377, TS C43716, Wang 14/106/4

Rock name Cross bedded quartz sandstone

Hand specimen

The specimen is a friable, brown, well sorted, cross bedded, quartz sandstone. Bedding is relatively fine and is marked by darker brown colour but not by any detectable grain size variations. Cross bedding is apparent in one set of beds.

Thin section

The framework is dominated by monocrystalline quartz grains with very minor polycrystalline lithic fragments. Tourmaline and zircon are moderately abundant as trace minerals. The zircon occurs as very fine grains with a tendency to be concentrated in heavy mineral bands rather than evenly distributed. Tourmaline grains are coarser and appear to be randomly distributed.

Grain shapes vary between well rounded with high sphericity to angular and elongated but the great majority of grains fall into the subrounded category. Shapes appear to be mainly the result of sedimentary processes rather than corrosion. Grain size variation is not great and appears to be random in distribution. The bedding of the sediment is expressed in a preferred orientation of elongated grains rather than in variations in grain size, or in mineralogy apart from the scattered zircons forming weak concentrations in heavy mineral bands.

For the most part the sediment is framework supported but in patches and bands which are oriented at right angles to the bedding a high porosity has been developed and has been partly filled with a brown stained clay. Even in the framework supported parts of the sediment there is a high interstitial porosity, the walls of which are lined with a coating which is brown in plane light and birefringent between crossed polarisers. This appears to be similar to the brown, birefringent coatings noted in specimen 6438RS375 but the brown material in RS377 merges with the brown clay in the highly porous regions and is almost certainly not a sulphate.

In places where a sedimentary matrix persists, it is a kaolinitic clay. In the framework supported parts of the sediment much interstitial material has been dissolved but the framework grains have remained unaffected apart from acquiring a brown coating. In the zones of strong solution the solution cavities are so large that many grains as well as matrix must have been removed. The large spaces have been partially filled with the brown material but a substantial porosity remains.

The brown material itself has a platy structure and a moderate birefringence. It is almost certainly a clay and a few small flakes of recognisable mica within it suggest that the clay is probably an illite rather than a montmorillonite. The brown colouration is probably limonite but may not be related to the origin of the muscovite.

Comment

Like most of the other specimens examined the rock has been subjected to an episode of dissolution by pore solutions after, possibly long after, sedimentation and lithification. In this instance the mineral introduced into the high secondary porosity is apparently a mica which later altered to a clay rather than a carbonate or sulphate.

DISCUSSION

The specimens examined are arenaceous sediments and include both quartzose and greywacke type lithologies. Most of the specimens have been subjected to substantial dissolution by pore fluids and a variety of minerals have been deposited in the cavities formed. The carbonates and sulphates were probably introduced at a time when the rocks outcropped or were close to the surface, as calcretes and gypcretes, but evidence is inconclusive in the specimen for which the introduced species was a mica, now represented by a brown clay.

The sulphate introduced as a gypcrete apparently consists of more than one species and may be of economic interest as a source of potassium. If this proves to be the case it would possibly be rewarding to screen a large number of gypcretes for their potassium content.

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