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# A CALCAREOUS CHANNEL SAND FROM THE ETADUNNA FORMATION NEAR WANGIANNA


## ABSTRACT

Specimens from the Etadunna Formation illustrate deposition by intermittent drainage in a possibly migratory channel. Well sorted quartz grains from a mature sediment were deposited with a carbonate mud as matrix in the channel and silty mud precipitated in backwaters. Intraformational mud pellets were deposited with a sandy mud matrix in places. Strong reaction between quartz clasts and an alkaline pore solution was active during evaporation of waterholes and during diagenesis. The solution evolved towards a calcic composition until after lithification was complete.


## INTRODUCTION

Thin sections and polished hand specimens were received for examination from Roger Callen of the Regional Geology Branch. The four samples were from a channel sand in the Etadunna Formation and information was requested on the maturity of the sand, the mineral content and the physical state and chemical reactivity of framework and matrix constituents.

## PETROGRAPHY

Specimen 6438 RS 520(A), TS C50744

A. Detrital Components

(1) Sand sized grains

(a) Mineralogy

Quartz 90% Siliceous lithic clasts 10%

b) Textures

The clasts are highly corroded and suspended in a carbonate matrix through which they are dispersed. They probably represent the remains of a more continuous sand or sandstone. Corrosion has affected the surface of the grains and has penetrated them along fractures and cleavages. In places the shape has been left as a well-rounded clast, sometimes by the removal of authigenic overgrowths on a nucleus inherited from a grain rounded in an earlier sedimentary cycle. For the most part the grains have been etched into irregular shapes and in extreme cases only a skeletal relic of the original quartz grain remains. Some quartz grains have been corroded along parallel planes. Since quartz has no cleavage, there are probable planes produced by directional stress at an earlier stage in the history of the grain.

Polycrystalline clasts consist mainly of recrystallised quartzites in which quartz grains are in close contact. In a few clasts the carbonate matrix has penetrated between the grains which may indicate the former presence of a matrix or cement in a sandstone sediment rather than a recrystallised quartzite.

Almost all clasts are surrounded by a zone of coarsely crystallised carbonate.

(2) Larger clasts

These are seen in the polished surface of the hand specimen and are of two types. One type is simply coarser grained examples of the same siliceous clasts as make up the sand grains. Size sorting is poor but strict sedimentary classifications cannot be applied. The second type is represented in the thin section as well as the hand specimen and consists of fine grained carbonate similar to the matrix of the specimen. The example in the thin section is rounded and is presumably derived from an earlier sediment of similar type. Sedimentation probably proceeded discontinuously with some reversals in which sediment recently deposited was broken up. The process was virtually intraformational.

Large clasts are also surrounded by a zone of coarsely crystallised carbonate.

B. Matrix

The matrix consists mainly of very fine grained, poorly crystalline to amorphous carbonate. The carbonate is not stained by alizarin red dye so is not calcite. It varies in colour from cream to brown and probably contains a varied but appreciable concentration of iron. It can be classified as an ankeritic dolomite with a small range of composition.

Thin bands of even finer grain size, with small shrinkage cracks, indicate that some, probably most, of the matrix originated as a carbonate mud. However, the extent of corrosion of many of the quartz clasts indicates that some, even of the amorphous carbonate, has been precipitated by post-depositional replacement of detrital quartz.

The clearest evidence of carbonate replacement of quartz is in fractures and around the margins of detrital grains where clear, well-crystallised dolomite has been precipitated. This is not to say that the original shape of the clast is replicated in crystalline dolomite. Recrystallisation is more
extensive than this since the margins of clasts have provided channels for the mobile pore waters through which medium both replacement and recrystallisation have occurred. Fractures and solution cavities throughout the matrix are also marked by coarse grained carbonate recrystallisation.

The latest carbonate precipitated in some pore spaces is a small quantity of calcite, identifiable by a deep red stain with alizarin red dyke.

C. Discussion

The full extent of recrystallisation is not clear but a possible sequence of events is as follows. At least some, if not the major part, of the fine grained carbonate probably sedimented out of rapidly evaporating water as a muddy deposit. Occasional influxes of water carried clastic detritus which included fragments of mud deposited and partially lithified earlier. These are essentially intraformational. The debris was deposited with a matrix of carbonate mud in an environment which either was or quickly became alkaline enough for corrosion of siliceous clasts to occur. Some clasts may have been completely digested and it is not possible to estimate whether sand grains were originally contiguous. It is not possible to estimate the original shape of the clasts either. The present shape is entirely the result of corrosion. Grains which were fractured or stressed were corroded internally and some were reduced to skeletal relics. Grains with a more resistant crystal structure were rounded or weakly embayed.

The solutions which corroded siliceous clasts precipitated carbonate in their place. The form of a phase precipitated from solution is related to the rate of formation of the solid. Sedimentation of carbonate mud probably took place rapidly as a flocculant precipitate of amorphous structure. Diagenetic and postdiagenetic deposition of carbonate was probably slower and resulted in a crystalline carbonate replacement product for the most part.  However, some replacement may have taken place quickly enough to consist of amorphous material.

Magnesium carbonate is more soluble than calcium carbonate and the recrystallised material is a non-staining carbonate, probably of high magnesium dolomite composition.  The last carbonate to precipitate in pore spaces takes a red colouration from alizarin red dye and is thus a low magnesium calcite.

The amount of recrystallised carbonate is greater in beds containing sand grains than in muddy beds in which the only passage for solutions is through open cavities.  The beds are irregular, probably due to movement in soft mud, and the sediment probably accumulated in a backwater of the channel where sand only penetrated at times of high water flow.

<u>Specimen 6438 RS 520(B), TS C50745</u>

<u>A.  Detail Components</u>

(1)  <u>Sand sized grains</u>

a)  <u>Mineralogy</u>

Quartz 95%, siliceous lithic clasts 4%, carbonate lithic clasts 12, zircon trace.

b)  <u>Textures</u>

The original textures of the siliceous detrital components are not identifiable owing to corrosion and replacement.  A few carbonate clasts are of sand grain size.  These are subangular to subrounded but, since they are surrounded by a layer of recrystallised carbonate, the extent to which the shape is original cannot be estimated.  Fractures in the clasts are filled with crystalline carbonate.

(2)  <u>Carbonate lithic clasts</u>

Larger clasts in this thin section are  lithic carbonate fragments.  These are darker in colour than the matrix carbonate and some contain fine quartz grains.  The carbonate is amorphous and probably ankeritic in composition.  Some clasts are fractured with two types of fracture filling.  One type is black and dendritic and may be composed of manganese dioxide.  Extensions of these fractures and, more abundantly, new fractures are filled with crystalline carbonate.

B. Matrix

The matrix consists of the same amorphous carbonate as was observed in RS 520(A)> In thin section it appears brown but of a paler shade than the carbonate clasts. Seen without magnification it appears pinkish.

The matrix is cut by irregular fractures, some of which are 5 mm wide. they are filled with three kinds of carbonate. The earliest is an extremely fine grained, dark grey, amorphous to poorly crystalline type. Inside this type, which coats the walls of the fractures, is a well crystallised, colourless, coarser grained type. The last stage is a crystalline carbonate which stains with alizarin red dye and is thus calcitic. This often fills the centre of the fracture. In some fractures fine grains of quartz have been carried in with the solutions precipitating carbonate.

The specimen contains many large cavities.

C. Discussion

The thin section is cut from the same specimen as RS 520(A). The lithologies are similar, differing only in mineral proportions apart from the presence of fine grained, dark grey carbonate. The greatest variation in mineral proportions is the greater abundance of intraformational carbonate fragments.

Specimen 6438 RS 521, TS C50746

A. Detrital Components

(1) Sand sized grains

(a) Mineralogy

Quartz 99%, lithic quartz clasts 1%, rutile trace, large lithic carbonate clasts trace.

b) Texture

Part of the specimen, and of the thin section, consists of a clast-rich sandstone in which quartz grains are almost in contact. It is possible that when deposited the sediment was framework-supported but that a carbonate matrix has since been inserted, partly by sedimentation but largely by corrosion and replacement of quartz grains. Because the proportion of mud was lower than in RS 520 and perhaps because the sand was better drained during diagenesis, the extent of corrosion is less in this part of RS 521. The grains are mainly equant, often well rounded and generally well sorted in grain size. Because some corrosion has evidently taken place a detailed analysis of grain shape would be misleading but it appears that the sand was a very mature sediment both chemically and physically. Corrosion in a few grains has removed part of an authigenic overgrowth but has preserved a well rounded nucleus. From this it appears that the source of the sediment was also a highly mature quartz sandstone, in this instance with a quartz cement.

A bedded fabric which is prominent in the hand specimen is seen in thin section to be more the result of changes in the relative proportions of clasts and matrix than of grain size variation, although the latter does occur to a minor extent in both clasts and matrix.  The same type of grains occur in a band adjacent to the sandy band as in the sand itself.  A much higher proportion of matrix is associated with a higher degree of corrosion of the quartz clasts.  The clasts are surrounded by a layer of crystalline carbonate and fractures are penetrated by the same material.  Some clasts are reduced to skeletal relics.

A band immediately adjacent to the sandy lithology is varied in the proportions of clasts and carbonate mud.  The band is bounded by a brown stained contact with the sand and a green stained contact with sandy mud on its other side.  In thin section the stains are both dark without visible colour.  they may be organic in origin.  The green band contains a higher proportion of clasts than the mud on either side of it.

The mud on the far side of the transitional band relative to the sandy band is particularly poor in clasts and rich in carbonate matrix.  The proportion of clasts progressively increased towards the end of the thin section where the sandy component tends to be finer in grain size than the average for the section.

(2)  Large clasts

The hand specimen contains a few of the larger clasts, composed of carbonate mud, recognised in specimen RS520.  Only the extreme end of one elongated example of these is represented in the thin section.  They consist of extremely fine grained, dark coloured carbonate matrix surrounding corroded quartz clasts and are probably intraformational, partially lithified mud.

B.  Matrix

Matrix surrounding the clasts in the sandy part of the specimen is largely recrystallised carbonate but retains patches of fine grained, amorphous material which is probably original muddy sediment.

The band immediately adjacent to the sandy layer also consists of very fine grained carbonate, forming the major part of the sediment, with well crystallised carbonate restricted to coatings around the quartz clasts.

The carbonate matrix in the rest of the section is relatively uniform and consists of fine grained but crystalline carbonate.  Quartz clasts are surrounded by layers of recrystallised, coarser grained carbonate.  Both the fine and the coarser grained carbonate penetrate fractures in quartz and eventually produce skeletal relics of clasts.

The major part of both fine and coarse grained carbonate is dolomitic since it is unstained or very weakly stained by alizarin red dye.  Strongly stained, red calcite is very rare and restricted to a few cavities open to pore water.

One feature visible in hand specimen but not represented in thin section is a zone marked by frequent cavities. At one point in this zone a central large cavity is surrounded by a concentric series of liesegang rings recognisable over a diameter of 4 cms.

c. Discussion

The specimen represents sediment closer to the drainage channel than RS520. Even here, however, the flow dried up between periods of flood, first decreasing the proportion of sand and increasing that of mud in its load and finally forming evaporating pools and alkaline groundwater similar to that in the backwaters represented by RS520. The direction of diminishing load may be the upward direction during sedimentation. Restoration of water flow possibly occurred rapidly with a short transitional period. Sediment was derived from a mature quartz sandstone.

Reaction between silica clasts and alkaline pore fluid again played a prominent part in the history of the rock.

Specimen 6438 RS 523, TS C 50743

A. Detrital Components

(1) Sand sized grains

a) Mineralogy

Quartz 83%, carbonate lithic clasts 15%, siliceous lithic clasts 2%, rutile trace, zircon trace.

b) Textures

The hand specimen is divided almost equally between well sorted sandstone and intraformational conglomerate with a sandstone matrix. the thin section contains sandstone, an intermediate facies and a large conglomerate clast.

The quartz grains are well sorted and mostly well rounded. Chemical corrosion is not as far advanced in RS 523 as in Rs 521, although most clasts are surrounded by crystalline carbonate. the amount of quartz removed, as measured by the distance between clasts which were probably at one time in contract, would not radically change the shape of the clasts. A few clasts have lost or partially lost authigenic overgrowths and are reduced to a well rounded nucleus. From the erosion of a mature quartz sandstone a deposit of mature sand has been derived. A few siliceous clasts are lithic and include silica which was originally colloidal.

A few dark, fine grained clasts of carbonate mud are of sand size, although coarser in grain size than the quartz clasts. The dark colour appears to be due to oxidised iron compounds. either the carbonate was originally a siderite or it became ferruginised by a lateritisation process when at or near the surface.

(2) Larger clasts

Dark, fine grained carbonate clasts vary in size between 1 mm and 4 cm. The largest in the thin section is 2 cm across. Several in the section are between 2 mm and 6 mm. Some consist only of dark, amorphous carbonate but others contain corroded quartz clasts. They originated as pellets of mud, some of it carrying sand. The large mud clast is coated with sandy mud as if it rolled across wet sandy sediment and picked up a layer of it as a snowball picks up snow. The clast itself is almost perfectly spherical. It is composed of dark, amorphous carbonate with scattered fine grains of quartz. these textural features are compatible with intraformational erosion, transport and sedimentation in which a fine grained silty mud originally deposited in quiet water is disrupted before lithification by flood water and the fragments are rolled across soft mud before incorporation in a pebble bed under flowing water. The scale of the process is indicated by the abundance of mud pellets. The water continued to carry sand grains after the pellets had been deposited. This probably indicates the facing of the sediment.

B. Matrix

The matrix of the sandy facies consists of dark amorphous carbonate similar to that forming the mud pellets and of clear, crystalline, non-staining carbonate coating some of the quartz clasts and penetrating fractures within them. In the facies containing mud pellets the matrix includes quartz sand grains in places.

The mud pellets have acquired a light pink colour from the alizarin red dye and thus consist of a dolomite or amberite with substantial calcium. Bright red-stained calcite occurs as lining to the walls of frequent open cavities and also fills fractures which cut sandy sediment and mud clasts alike. Deposition of calcite thus appears to be a post-lithification process.

C. Discussion

The specimen completes evidence for the presence of a channel of intermittent drainage in which carbonate mud and fine silt were deposited in quiet, evaporating backwaters and pools in the main channel. the return of water brought with it quartz sand eroded from a mature sediment and also disrupted mud deposited after the last wet period. The channel itself may have wandered across terrain of limited relief. The terrain was possibly analogous to the present day channel country.

Post-depositional reactions between silica clasts and alkaline pore water continued during diagenesis and the evolution of carbonate solute towards a calcium rich composition persisted into the post-lithification period.