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Devonian Braided Stream Deposits in the Battery Point Formation, Gaspé Est, Quebec*

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Introduction

In the past five years, study of braided stream systems has increased markedly. By far the bulk of the work has been done on modern streams and their deposits, with very little investigation of ancient sediments. To the author's knowledge, no study of ancient braided stream deposits exists which analyses those deposits for a system of facies changes in a vertical direction, such as the fining upwards cyclothems of meandering systems (Allen, 1964, 1965).

Consequently, a study of the deposits of an ancient braided stream system has been undertaken, to provide a description of the deposits involved, but also with particular emphasis on investigation of any system of vertical facies repetition, or cyclicity. In order to investigate this fully, it is necessary to study similarities and differences between these ancient deposits and descriptions of modern stream deposits (Doeglas, 1962; Fahnestock, 1963; Coleman, 1969; Williams and Rust, 1969; Collinson, 1970; Smith, 1970; Church, 1972; Rust, 1972a). Intregration of knowledge of sedimentary structures, and paleocurrent data into the stream is necessary to develop fully any facies model.

The rock unit chosen for the study was the lower part of the Battery Point Formation (Devonian) exposed on the north shore of the Bay of Gaspé, Province of Quebec. This formation is thought to be fluvial because it exhibits characteristics such as large scale channelling, fine members overlying coarse members (in part), basal conglomerates, plant fossils, in situ plant fossils, and fresh water fish fossils. These characteristics have been recognized as indicative of fluvial successions (Allen, 1965).

The lower part of the unit is thought to be the result of deposition by a braided stream because it exhibits many of the characteristics of those deposits (Ore, 1963; Smith, 1970). Some of these are the presence of many planar, tabular crossbed sets, many shale beds and intraclast horizons, the discontinuous nature of the bedding, the poor sorting of the sediment, and above all, the extreme paucity of shale, mudstone, or siltstone in the section.

General Description and Setting

The Battery Point Formation, of Lower Devonian age, (Boucot et al., 1967) is a molasse sequence related to preliminary events of the Acadian orogeny. It is mainly a grey to red sandstone, pebbly in places, composed dominantly of quartz and feldspar grains, but with chert, jasper, and rock fragments also present. In the upper part of the formation, thick red to brown mudstone and siltstone layers are developed.

The formation was mapped by the Quebec Department of Mines (McGerrigle, 1950), and is part of the Gaspé Sandstones, a group of marine to non-marine clastics which overlie the wholly marine Lower Devonian Gaspé Limestones.

The basal unit of the Gaspé Sandstones, the wholly marine York River Formation, is overlain conformably by the Battery Point Foramtion, so the Battery Point is the first continental deposit in the sequence. The overlying Malbaie Conglomerate is probably also continental in origin.

Methods of Study

The field work consisted of the description or characterization of a seashore section approximately perpendicular to the strike of the moderately dipping beds. The first step was to do a reconnaissance measurement, picking out any major units which could be distinguished. Within each of these major units, individual subunits with internal homogeneity of sedimentary structure and grain size were then measured. Within these subunits, sizes of individual sedimentary structures were measured, as well as mean grain sizes, and maximum grain sizes, by means of a hand lens and scale. An attempt was made to characterize the grading from coarse to fine laminae, and down crossbeds by measuring mean grain sizes at appropriate locations. It was found that measurement of these grain size parameters was insufficient to characterize the sediment completely, because the grain size distribution is usually bimodal, with one mode in the sand range, and another in the granule to pebble range. For the purposes of this study, a pebble is defined as any grain with a mean diameter of three millimetres or greater. Each subunit, therefore, was assigned an index of pebbliness, defined as the average number of pebbles per square foot, in vertical section, based on visual estimate. The mean diameter of material in the size range was also estimated, so the volume percentage of pebbles in each subunit can be calculated.

Although lateral exposure is infrequent, particular attention was paid to what did exist, as it was felt that consideration of any lateral changes would greatly clarify facies relationships.

Results of this Point

A detailed vertical section has been built up through about 350 feet of strata. This section is more or less continuous except for small covered intervals or faults which cannot be correlated across those features. It is felt, however, from a study of movement on other faults in the section, that no large vertical displace-

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ment has taken place, as adjacent faults in places show opposite sides downthrown, indicating a general adjustment, with no accompanying major tectonic activity.

The section is composed largely of sandstone showing the following structures; trough crossbeds, planar tabular crossbeds, a type of scour filling, low angle cross-laminations to parallel laminations, and in a few places, ripple cross-laminations. Very little shale or mudstone is present except in the form of intraclasts.

Trough Crossbeds:

Inspection of the section diagram (Fig. 1) reveals trough crossbedding to be the single most common sedimentary structure. Subunits completely composed of this structure in many cases show remarkable uniformity, with many crossbeds of extremely similar thickness and grain size developed both laterally and vertically.

The trough crossbeds are scoured into one another in almost all cases, making it impossible to gauge the original size of each structure; however, it is thought that maximum thickness preserved is the parameter measurable in outcrop which best characterizes the size of the trough crossbed. In the section measured, the troughs range in maximum thickness from three inches to twenty-one inches, with the majority around eight inches. The radius of curvature of the troughs increases with increasing thickness; that it, the thicker the trough crossbed, the shallower the angle of the trough base.

These structures commonly show grain size grading down the foresets, with coarser material nearer the base. Some of the troughs cut into exposed surfaces were filled obliquely, as the grading is asymmetric, and the laminae pinch out against the side of the scour. Some of the exhumed scours also appear never to have been filled by material like that in which they were cut, but filled only by finer sediment composing the next subunit.

Planar Tabular Crossbeds:

The second most common sedimentary structure present is planar tabular crossbedding. In the section, it ranges in thickness from three inches to ten feet, occurring in groups when small, but usually (not always) as solitary sets when large.

The larger solitary sets are developed, in most cases, on a very flat base, are coarser grained, and show grain size grading down the foreset. In some exposures, the foreset can be traced for a few feet along its original strike, and very little, if any, curvature can be seen. In addition, these foresets can sometimes be seen to terminate, with replacement downcurrent, usually by small trough crossbeds.

The smaller sets exhibit many characteristics contrasting with these. They commonly show some slight scouring at each base, are finer grained, show little grading and sometimes have a tendency to be slightly asymptotic.

It is probable that these two types of structures differ somewhat in modes of origin, so a different terminology should be used for each in future work on the section. There is no sharp set thickness division for the two types, but the general aspect, involving the characteristics discussed are usually sufficient to discriminate between the types.

Scour Filling:

This structure is infrequent in the section, occurring mainly at one locality near the base. The scours are large, up to ten feet in width, three feet in depth, and are filled by fine sand to a granule-sand mixture. The shapes are variable, from a symmetric scoop, to an asymmetric scour, to a very low angle, almost float depression. The laminae which infill these erosional features are not at the angle of repose, commonly showing ripple cross-laminae and internal erosional features, so it is felt that infilling was a more or less gradual process.

Low Angle Laminations:

Another sedimentary structure of unknown origin is present. In vertical section it appears to be composed of very low angle cross-laminae which grade laterally, in places, to parallel laminations. In many exposures, some type of grain lineation is seen on upper surfaces; however, it is not known if this is an upper flow regime parting lineation, because it is usually vague and poorly defined. This structure and its origin will be discussed again in the next section.

Intraclasts:

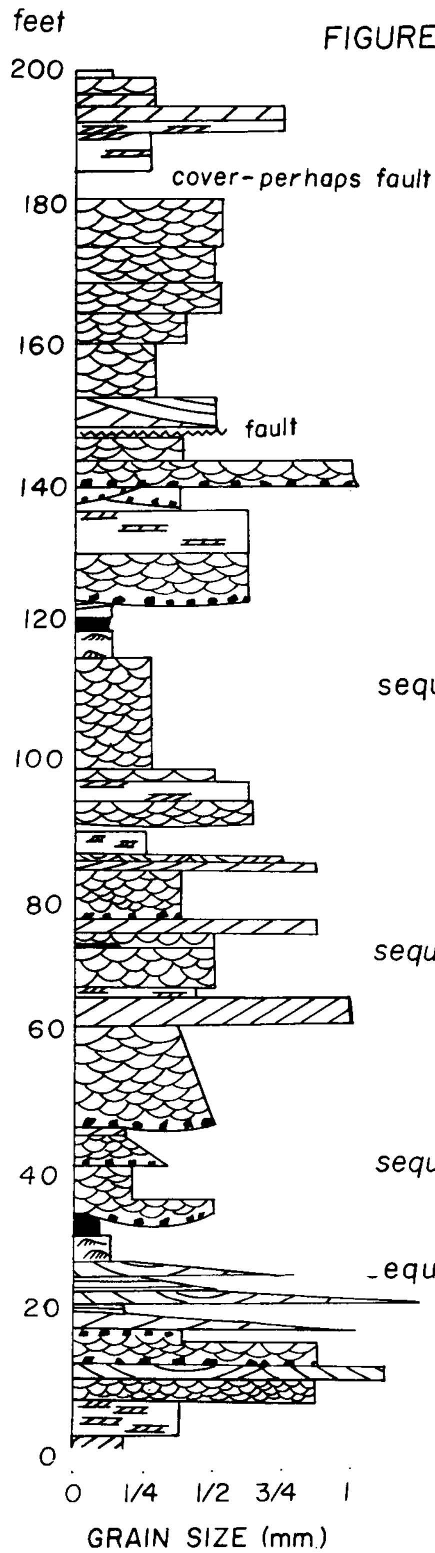
Layers of shale, mudstone, or siltstone intraclasts (or moulds of weathered out intraclasts) are extremely common throughout the deposit, much more so than continuous shale layers. The layers of angular to subanbular intraclasts almost always occur at the bases of subunits, very commonly on scoured surfaces. The clasts average two inches in diameter, but occasionally reach ten inches.

Vertical Facies Sequences

It was found that the section consisted of a number of sequences which contained several common basic elements (see Figs. 1-4). These include: (1) a basal scour into the underlying material; (2) an irregular layer of intraclasts at the base; (3) a subunit at the base composed of trough crossbeds; (4) an overall grain size change upwards from coarser to finer.

Discussion of Similarities:

(1) The scour into the underlying material varies



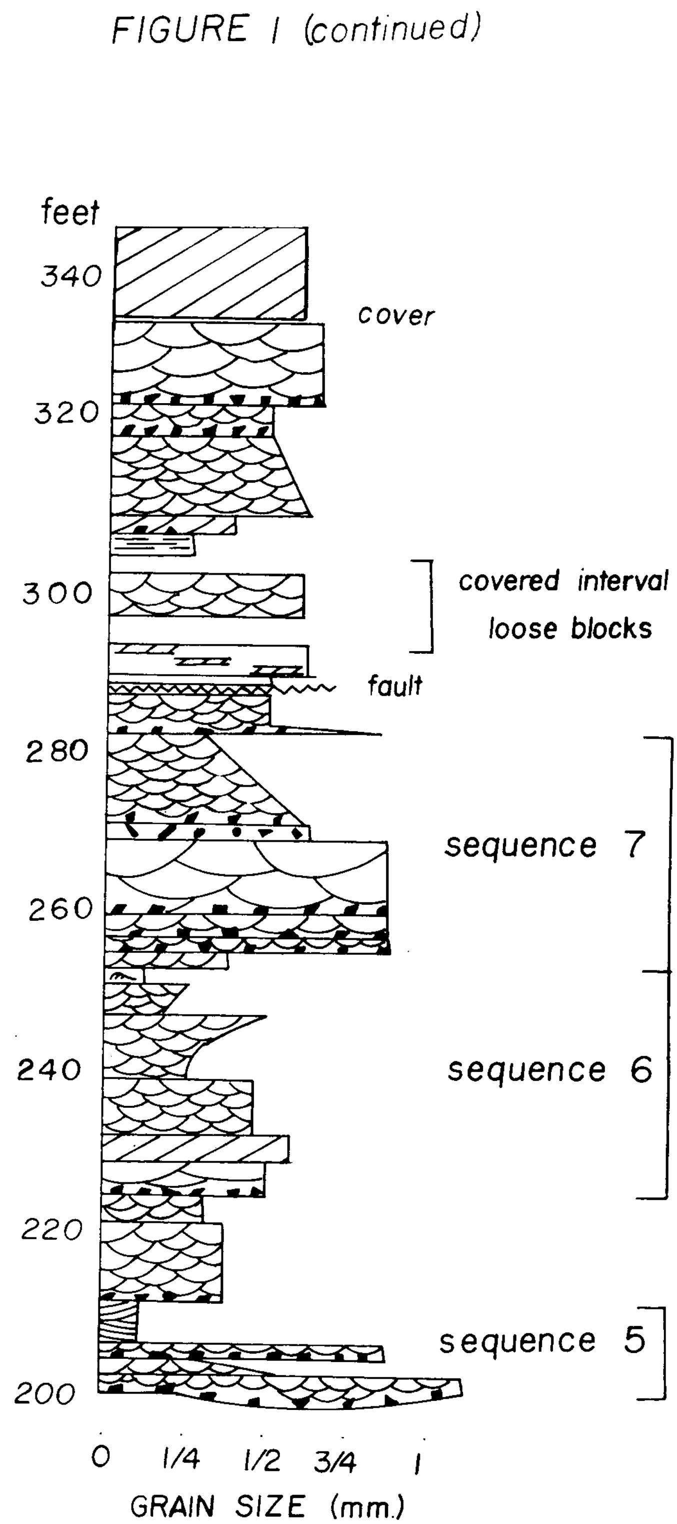


Fig. 1 - A diagramatic presentation of the measured section with the recognized sequences indicated.

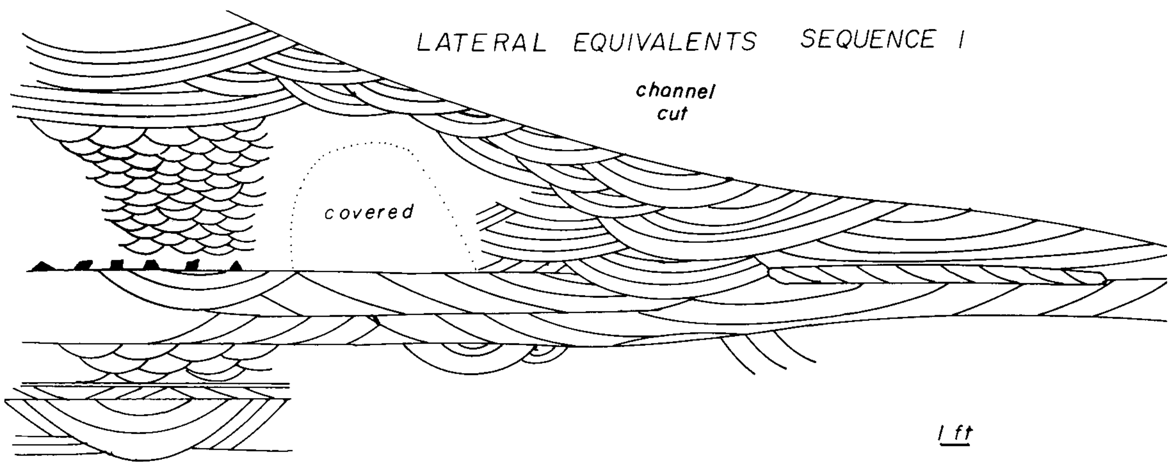


Fig. 2 - Trough-cross beds changing both laterally and vertically into large scour fillings in which the internal laminae are not at angles of repose.

a great deal in magnitude, from only an irregular erosion surface (sequences 1, 3, 5, 7) to a full-scale channel which cuts down about fifteen feet (sequence 2). However, every base that is exposed rests on some form of eroded surface.

(2) At each exposed base, an intraclast layer is developed to a greater or lesser extent, presumably depending on the amount of erosion of mud beds. The deeply channelled base of sequence 2 shows a higher concentration of intraclasts than any of the flatter erosion surfaces.

(3) Each of the sequences starts off with a subunit of trough crossbeds, suggesting a common mode of origin for at least the lower part of the sequences. The thickness of the subunits, and average trough size in the subunits varies a great deal from sequence to sequence.

(4) The upwards grain size change, from dominately coarser sediment near the base, to dominantly finer near the top, is present in each sequence. This change is valid in a general way in spite of the many irregularities and reversals seen in specific cases. Sequences 2 and 5 are perhaps more irregular because they appear to be composites of smaller channel filling events. Some of the other sequences (3, 7) do not show much fine material near their tops, but this is probably because of erosion by the next major event in the system.

Differences:

There is a great deal of variability in these sequences as one would expect from the deposits of a highly complex and active system such as a braided stream. These differences include: (1) the presence in some sequences of large sets of planar tabular crossbeds; (2) development of intraclast horizons within the bodies of several sequences; (3) grain size fluctuations; (4) nature of the deposits near the top of the sequences.

Discussion of Differences:

(1) The presence or absence of large scale planar tabular crossbeds is at least partly due to poor lateral exposure. Some of the crossbed sets can be seen to terminate and be replaced downcurrent by small to moderate sized trough crossbeds, suggesting that although the two types of structures differ, they may be formed under similar environmental conditions.

(2) Intraclast layers within each sequence are good indicators of fluctuating conditions within the stream system, as deposition of fine material took place at one time, and erosion at another, implying rapid changes of flow and depth conditions (Smith, 1972). Intraclast-rich horizons are very common in sequence 2 which is known to be a multiple storey channel fill by consideration of lateral relationships. These horizons are also common in sequence 5, which also looks like a composite sequence.

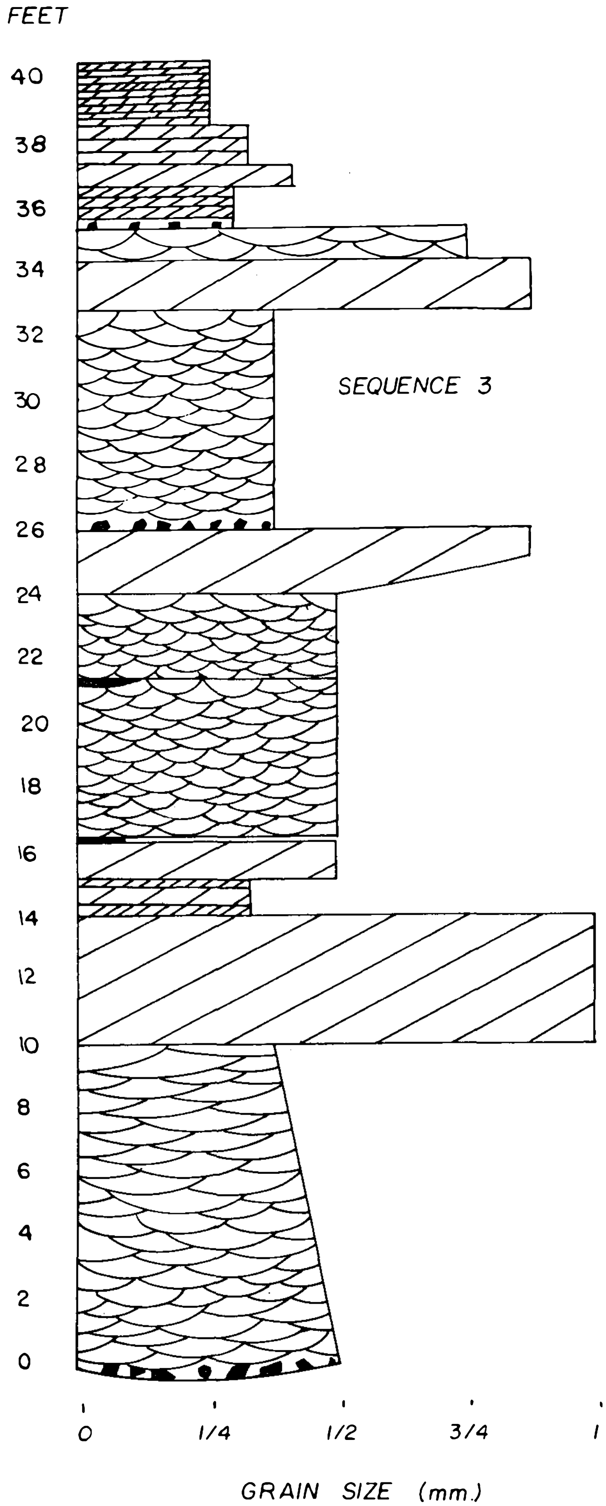


Fig. 3 - A typical sequence showing the scoured intraclast - strewed surface at the base, the trough-crossbedded units inter-bedded with planar tabular crossbeds and the finer material at the top.

Sequence 7 contains a large number of intra-clasts scattered through the sequence at the bases of large troughs as well as in layers. Presumably, as troughs were cut into intraclast strewn surfaces, the clasts remained behind as a lag deposit, generally ending up trapped in the bases of troughs.

(3) Grain size fluctuations in the sequences are consistent with the irregular discharge of a braided stream. In the Lower Devonian, very little terrestrial vegetation was present to control runoff from the land, so extreme diff-erences in stream velocity, discharge, and sed-iment load would have been common. Very few reactivation structures are seen, however, so it is inferred that the water level did not fall far enough to expose bed forms in most cases (Collinson, 1970). At any rate, fluctuations of velocity and discharge were sufficient to cause rapid grain size changes.

Another factor may complicate the system however. In braided streams, branches rapidly shift across the alluvial system, so the grain size of the deposit at a given point may be changed a great deal by an anabranch migrating across that point. Even the migration of a branch slightly upstream from a point may have an important effect at that point by capturing most of the flow that previously passed. Although the system is extremely complex, it can be seen that there are two main factors controlling grain size at a point; overall velocity-discharge fluctuations in the stream system, and local velocity-discharge fluctuations due to anabranch migration.

(4) The topmost deposit in each sequence will be influenced by the extent to which it has been eroded. Sequences 1, 4, and 6 all have shale and fine rippled sand near their tops, indicating a very low flow regime during deposition. Sequence 3 has a large number of very small tabular crossbeds in fine sand, probably related to migration of some type of ripples, also a lower flow regime structure. Sequences 2, 4, 5 and 8 all have low angle cross-lamination to parallel lamination of unknown origin at the top. The lineations on the upper surfaces may be upper flow regime with actual velocity unspecified, because the flow may have been very shallow (see section on Interpretation below). Sequence 7 appears to have been truncated by erosion.

In conclusion to this discussion of the sequences, it can be said that in spite of the very large differences, a cyclic succession of repeated facies is present. The variability of individual sequences renders the pattern of the succession somewhat cryptic. However, a system has been found which appears to apply to the braided portion of the Battery Point Formation, even in the poorly exposed part above the measured section. In the final analysis, this applicability of the system of repeated facies is the criterion by which that system will be judged.

Interpretations

Very little interpretation has been done, but some inferences and general thoughts will be presented.

Trough Crossbeds:

These structures were probably generated by scouring in the lee of moderate sized dunes migrating downstream (Harms and Fahnestock, 1965). It is not known what factor or combination of factors controls the depth of scouring of the troughs, but dune size, stream velocity, sinuosity of the dune crest, and erodibility of the bed material probably contribute. The subunits composed of many identical trough crossbeds indicate that conditions were static for considerable lengths of time. Further work will be required for proof, but it appears that a general correlation exists between trough thickness and grain size in that trough.

Planar Tabular Crossbeds

The small planar tabular crossbeds are the deposits of dunes migrating downstream, which for some reason were preserved. Why the preservation potential of these dunes was different from that of the dunes that generated the trough crossbeds is unknown.

The larger, usually solitary planar tabular crossbeds are the result of downstream growth of transverse bars (Smith, 1970). Whether these bars had straight crest lines, or were sinuous, like the lingoid bars of the Tana River in Norway (Collinson, 1970) is unknown. No reactivation structures were seen in these large sets such as Collinson commonly found, suggesting that the discharge fluctuations did not leave these bars exposed to wave reworking. However, some of the bars do show troughs cut into their upper surfaces, which indicates reduced flow over the bar (Collinson, 1970), with smaller dunes migrating over the top. The termination of the bar and replacement downcurrent by trough crossbeds suggests that these structures are formed under similar conditions.

Scour Fillings:

The scour fillings appear basically at one point in the system, at 20 feet. They are probably the result of small channel cuts which were slowly filled by sediment coming in as discrete laminae rather than as foresets at angle of repose, as shown by ripples and internal erosional features. In this case, the lateral relationships simplify the interpretation. One subunit composed of moderate sized (8 inch) trough crossbeds is overlain by the large scour fills, above which is a sequence of shale beds and rippled sands, indicating a declining system. The trough crossbeds pass laterally into more of the scour fills by gradual replacement. A coarse, pebbly subunit immediately below the troughs shows a change in the same direction, from coarse, very pebbly sandstone to medium sandstone, with very few pebbles. These facts seem to indicate that the scour fills were cut and filled in the less active part of the system, perhaps in more shallow water than the troughs. The vertical change is probably due to the channel filling, and the scours developing in the shallower water. They were probably cut during high flow stage when the shallower parts of the system become utilized to pass the additional discharge.

Low Angle Laminations:

The low angle cross-laminations occur only at the tops of the sequences and as such, are an important element in the interpretation of those sequences. The origin of the structures is unknown: they may be beach deposits on bars within the river (Collinson, 1970), wind deposits, low amplitude sand waves (Smith, 1971a), or fillings of features called ellipsoidal scours (Williams and Rust, 1969).

In one place above the measured section, the upper twenty feet of a sequence composed almost entirely of this structure is exposed. The laminae change laterally to ripple cross-laminations, and are very close to in situ plant roots. The lineations on the tops of the laminae may be an upper flow regime feature created in very shallow water like the lineation in the swash zone of beaches (see interpretation of sequences below). Regardless of the origin of these structures, they are easily recognized, and are useful markers of the tops of sequences. By use of these structures, sequences have been noted in the poorly exposed portion of the formation above the measured section.

Intraclast Layers:

The intraclast layers indicate discharge fluctuations within the system with deposition taking place at a certain stage, then erosion at a higher one. This variation of discharges was a frequent occurrence, as intraclasts of shale are very erodible, and do not travel far before being rounded, then destroyed (Hein, 1971; Smith, 1972). These intraclasts accumulated as lag layers, so they indicate a part of the channel which had at least enough flow to remove some fines. This is also shown by the fact that intraclasts generally occur nearer the bases of the sequences than the tops (see interpretation of sequences below).

Sequences:

The interpretation of the sequences is in a very rudimentary state, but from their dominantly fining upward nature, and the sedimentary structures, it can be said that each sequence represents the deposits of a waning current system. Each probably represents the deposits of a major channel, with many bars and abranches within it, i.e. a first order channel in the terminology of Williams and Rust (1969). The waning flow of the system probably occurs due to the progressive filling of the channel as deposition proceeds, with correspondingly less flow coming down this part of the system. Unlike the model of meandering streams, probably all of the deposition took place within the boundaries of channel system, with no vertical accretion deposits outside the channel being formed.

The erosion at the base of each sequence took place as a major channel migrated across the braided system, or when flow patterns shifted and a completely new channel was cut. This probably occurred at very high stage during rapid discharge change (Coleman, 1969).

The intraclasts on the channel floor are lag, created by the erosion of locally deposited mud layers as discussed above.

The trough crossbeds, with which each sequence starts, are almost certainly deposited within the channel when it is carrying a large flow and is an active branch of the system. This is borne out by the fact that intraclast lag was deposited in some of these channels at the same time, indicating local erosion was occurring. Deposition of shale layers indicates a low water stage, but when is unclear. Some of the channels, at this point, had transverse bars developed within them, laying down the large planar tabular sets of crossbeds so prominent within the section.

As this stage proceeded, with many trough crossbeds deposited, the channel system began to be filled closer and closer to local mean water level, so flow down the channel diminished gradually. Eventually, very little flow came down this portion of the stream, except at high stage when the scour fills were created, and bodies of rippled sand and shale were deposited in some cases. The low-angle laminae were deposited by some process in what, by this stage of the sequence, must have been a very shallow flow, possibly a sheet flood.

Williams and Rust (1969) found that the deposits of the Donjek River, Yukon Territory, showed a fining upward trend, but several differences exist between the Donjek and the system studied. First, the Donjek is a sandy to gravelly proximal system whereas the Battery Point was deposited by a sandy, distal system. Also, the Donjek is a degrading or downcutting system, so the oldest deposits are at the top, in contrast to the system under study, which was aggradational. With the exception of this report, the author knows of no fining upward sequence reported previously from braided stream systems or their deposits.

Conclusions

(1) The lower part of the Battery Point Formation was deposited by a braided stream. (2) The sandy nature of the deposits and the presence of many planar tabular crossbed sets indicate the stream was distal in the classification of braided streams (Smith, 1970). This fits very well with the relatively rapid upward change in the formation to a meandering stream deposit. (3) A system of vertical facies repetition has been found in this braided stream deposit. (4) The sequences,

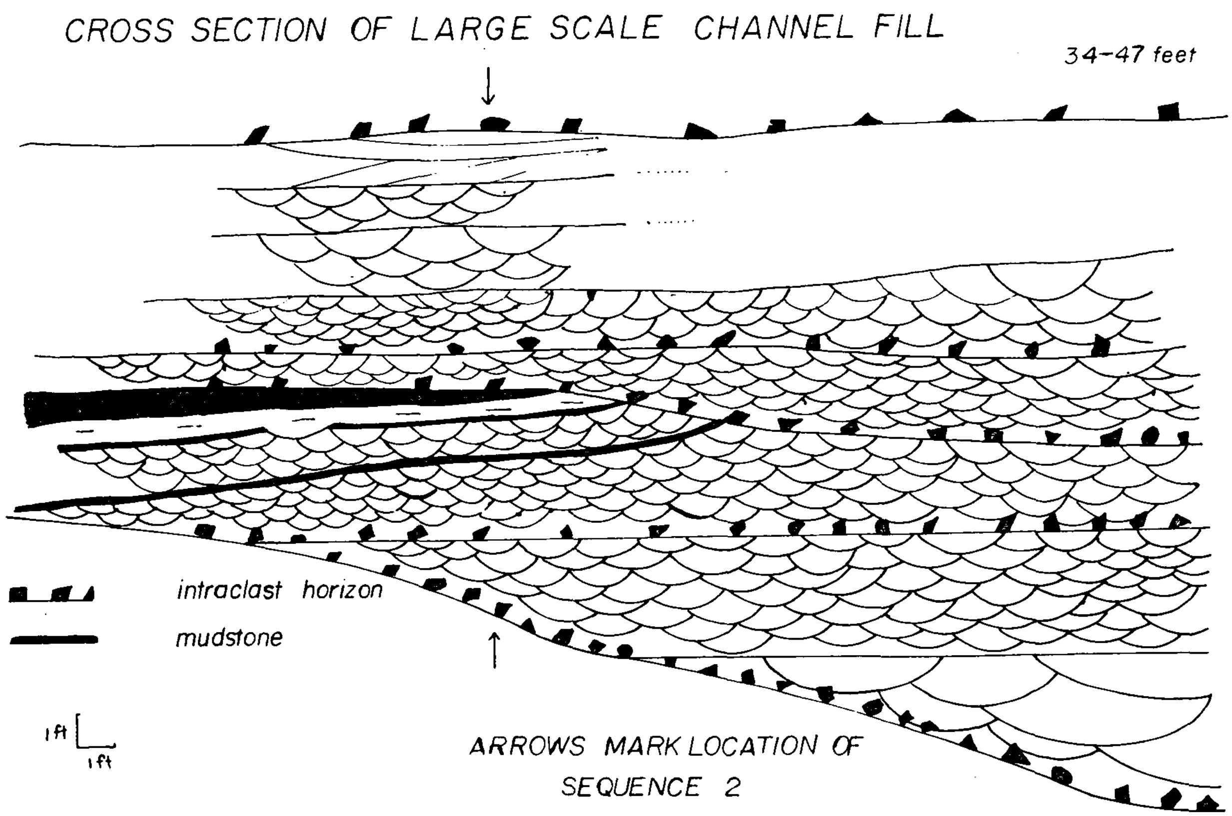


Fig. 4 - Mutistorey fill of a large channel in which intraclasts horizons mark off successive units.

which fine upwards overall, have scoured bases and a basal intraclast layer. The bulk of each sequence is composed of trough and planar tabular crossbeds which pass upwards, in most cases, into rippled sand and shale beds. Many sequences are topped by low angle cross-laminations which may change laterally to parallel laminations. (5) The sequences are caused by a system of waning currents which result from the filling of one part of the channel system, with progressive reduction of flow. (6) This study has shown that knowledge of modern braided stream systems is far from complete. (7) It is apparent that several models exist explaining different types of braided stream deposits, but that no unifying theory exists. It is also not clear what is the relationship between a distal braided stream and a meandering stream. It seems likely that a continuous gradation exists between the two.

Further Work

In general: - (1) Integration of paleocurrent data into this preliminary interpretation is of prime importance. (2) Most of the rest of the work will involve interpretation of the structures seen, by actualistic means, working from the descriptions in the literature of modern braided streams and their deposits. (3) No major amounts of field work will be required if the project remains at its present magnitude, only some checking details.

Specifically:- (i) Interpretation of the low angle to parallel laminations seen at the tops of many sequences is of major importance. (ii) It is necessary to determine, as closely as possible, the mechanism which controls the development of the sequences. (iii) An understanding should be developed of the formation of transverse bars; apparently they may develop from coalescing dune fields (Smith, 1971-b), which raises the question of how much, if any, of the troughed material underlying the planar tabular sets should be considered part of the transverse bar.

Acknowledgements

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