3. Facies C Mudstones

Mudstone occurs within sandstone beds, either centrally or more commonly near the top of the bed, as distinct laminae and very thin beds (Plate 6.3h, Fig. 6.1f). Such are either solitary or occur in sequences up to 20cm thick of interbedded laminae and very thin beds of mudstone and fine to medium sandstone. The solitary laminae are often of short lateral extent, their form suggesting deposition upon irregular sandy surfaces. The mudstone-sandstone sequences may extend for at least 10 metres along strike (MS31).

In MS31 and MS26 thin mudstone layers were observed to drape asymmetrical ripple marks (Fig. 6.2g). In MS29 thin mudstone layers occur draping cobbles protruding above an original sand bed surface (Fig. 6.2g,h). The mudstones in some instances exhibit delicate load structures, flame structures and other soft sediment deformational features.

The mudstones are often laterally terminated by scours. In some instances layers of mudstone clasts occur within the sandstones (Fig. 6.2j). It was not possible to show whether these mudstone clasts were derived solely by the erosion of pre-existing mudstone beds, solely by resedimentation of dessication cracked layers, or by a combination of both.

4. Facies D Interbedded Mudstone-Sandstone

Thicker mudstone sequences, up to 4.5 metres (MS28) with interbedded very thin to occasionally thick bedded fine to coarse sandstones, occur in MS31 and MS28. Plant detritus, parallel lamination, ripple cross lamination, possible interference ripples, small scours, load casts, flame structures, soft sediment deformation features, and mudstone fragment breccias have been observed. The overlying facies A conglomerate may fill shallow scours cut into this facies.

C. THE MARINE DOMAIN OF SEDIMENTATION:

Within the marine domain ten facies have been recognised (Table 6.1).

These facies are:

Facies E clast supported coarse conglomerates	common
E1 massive conglomerates	common
E2 graded conglomerates	common

Facies F matrix supported coarse conglomerates	uncommon
Facies G diamictites	rare
Facies H graded pebble conglomerates	common
Facies I graded pebbly sandstones	common
Facies J graded sandstones	common
Facies K sandstones	common
Facies L massive sandstones	common
Facies M interbedded mudstones - sandstones	common
Facies N massive mudstones	rare

1. Facies E Clast Supported Coarse Conglomerates:

These are by far the most common of the coarse conglomerates within the marine domain.

Textures: These conglomerates are of pebble-cobble and pebble-cobble-boulder grades with less common pebble, cobble-boulder and boulder grades (Plate 6.4a,b). Considerable textural variation is evident. The matrix is invariably a coarse to very coarse grained sandstone often containing plentiful small pebbles and granules. Where the matrix is better sorted bimodal size distributions occur, but where it is poorly sorted a polymodal size distribution will occur. Fabric data from this conglomerate facies have been fully described in Chapter 4. A reasonably well developed to pronounced imbrication (Plate 6.4d, Plate 2.1) and a preferred orientation of the A axes is evident in almost all samples (Fig 4.1).

Structures: Stratification within sequences of these coarse conglomerates is defined by variation in grain size, variation in sorting and the presence of sandstone layers (Plate 6.4c,e). Beds thus defined range from medium to very thick. No cross stratification has been observed.

Two basic types of conglomerate within this facies have been recognised; they are Massive Coarse Conglomerates (Facies E1) and Graded Coarse Conglomerates (Facies E2). 134 beds from 16 sections containing coarse clast-supported conglomerates could be assigned to either one of these two categories. In frequent stratigraphic intervals of poorer outcrop, e.g., isolated outcrops separated by often only small intervals of soil or alluvium, no conclusive determination of the type is possible; a pebble conglomerate above a pebble-cobble conglomerate could alternatively represent one graded bed or two separate massive beds.

Plate 6.4

a. Facies E coarse clast supported conglomerate. Note well rounded clasts. Tape is 20cm long. MS8.

b. Facies E coarse clast supported conglomerate. Tape is 20cm long. MS8.

c. Outcrop of facies E coarse clast supported conglomerates and facies L massive sandstones. Base of Jacob staff rests on a discontinuous layer of facies M interbedded mudstone-sandstone. Locality of fabric study F8.14. MS14.

d. Facies E coarse clast supported conglomerate. Note imbrication of larger clasts. Locality of fabric study F9-21. MS21.

e. Facies E2 graded coarse clast supported conglomerates. Two normal graded (graded-bed model) conglomerates separated by a facies L massive sandstone. MS8.

f. Normal graded facies E pebble conglomerate, passing up to a sandstone. (Top to right). MS5.

g. Inverse grading in a facies E conglomerate. MS20.

h. Facies E coarse conglomerate filling a scour channel which truncates a facies L massive sandstone. Some parallel lamination is evident in this particular facies L sandstone. MS14.

Plate 6.4

Table 6.2. Facies E Conglomerate Types

FACIES E	Clast supported coarse conglomerates			134 Beds
FACIES E1	Massive coarse conglomerates			78 Beds (58%)
FACIES E2	Graded coarse conglomerates			
	Normal graded type	(43%)	24	
	Inverse to Normal graded type	(20%)	11	
	Inverse to Massive graded type	(25%)	14	
	Reverse graded type	(12%)	7	
				56 Beds (42%)

Normal grading: 63% of graded types, 25% of all Facies E conglomerates
Inverse grading: 57% of graded types, 24% of all Facies E conglomerates

a) Facies E1 Massive Coarse Conglomerate:

The massive coarse conglomerates comprise 58% (78 of 134 beds) of the categorised conglomerate beds. The conglomerates are of pebble-cobble and pebble-cobble-boulder grade, with subordinate pebble and occasional boulder grades. They lack any grading of clast size throughout the bed. The beds are usually thick to very thick, up to 12 metres in MS17 and MS38, with the pebble or boulder conglomerates occasionally being of medium bed thickness. The possibility that many of these very thick beds may in fact be composite, consisting of more than one sedimentation unit, must be considered. Imbrication is evident in suitable exposures of the massive coarse conglomerates and has been demonstrated in other instances, along with a preferred orientation of the A axis, by fabric studies (Chapter 4). The A axes are oriented parallel and/or perpendicular to the inferred flow directions.

The massive conglomerate facies usually occurs in thick sequences interbedded with the graded conglomerate facies. When overlying sandstone or mudstone, basal scours may be evident (Plate 6.4h). Mudstone clasts occur within some massive conglomerates (Plate 6.5a,b).

b) Facies E2 Graded Coarse Conglomerates:

The graded conglomerates constitute 42% (56 of 134 beds) of the categorised conglomerate beds. Four types of grading are recognised; normal grading, inverse to normal grading, inverse to massive grading and

Plate 6.5

a. Large intraformational mudstone clasts (X) in facies E coarse conglomerate filling channel in MS5.

b. Large intraformational mudstone clast in facies E coarse conglomerate. MS39.

c. Facies F matrix supported conglomerate. Matrix is a small pebble bearing sandstone. MS19.

d. Facies F matrix supported conglomerate. Matrix is a muddy coarse sandstone. MS3.

e. Large intraformational mudstone block within channel filling facies F matrix supported coarse conglomerates, MS3. Arrows indicate conglomerate (to left) above, laterally adjacent to, and below the block (to right). Note "truncated" bedding in block. Hammer lies along line of contact. MS3.

f. Detail of block in 6.5e. Cobbles and boulder pressed into the mudstone of the block.

g. Facies G diamictite. Mudstone matrix with rare, isolated pebbles near hammer head, and relicts of original stratification. Hammer handle indicates present bedding attitude of the adjacent rocks. MS14.

h. Facies G diamictite. MS14.

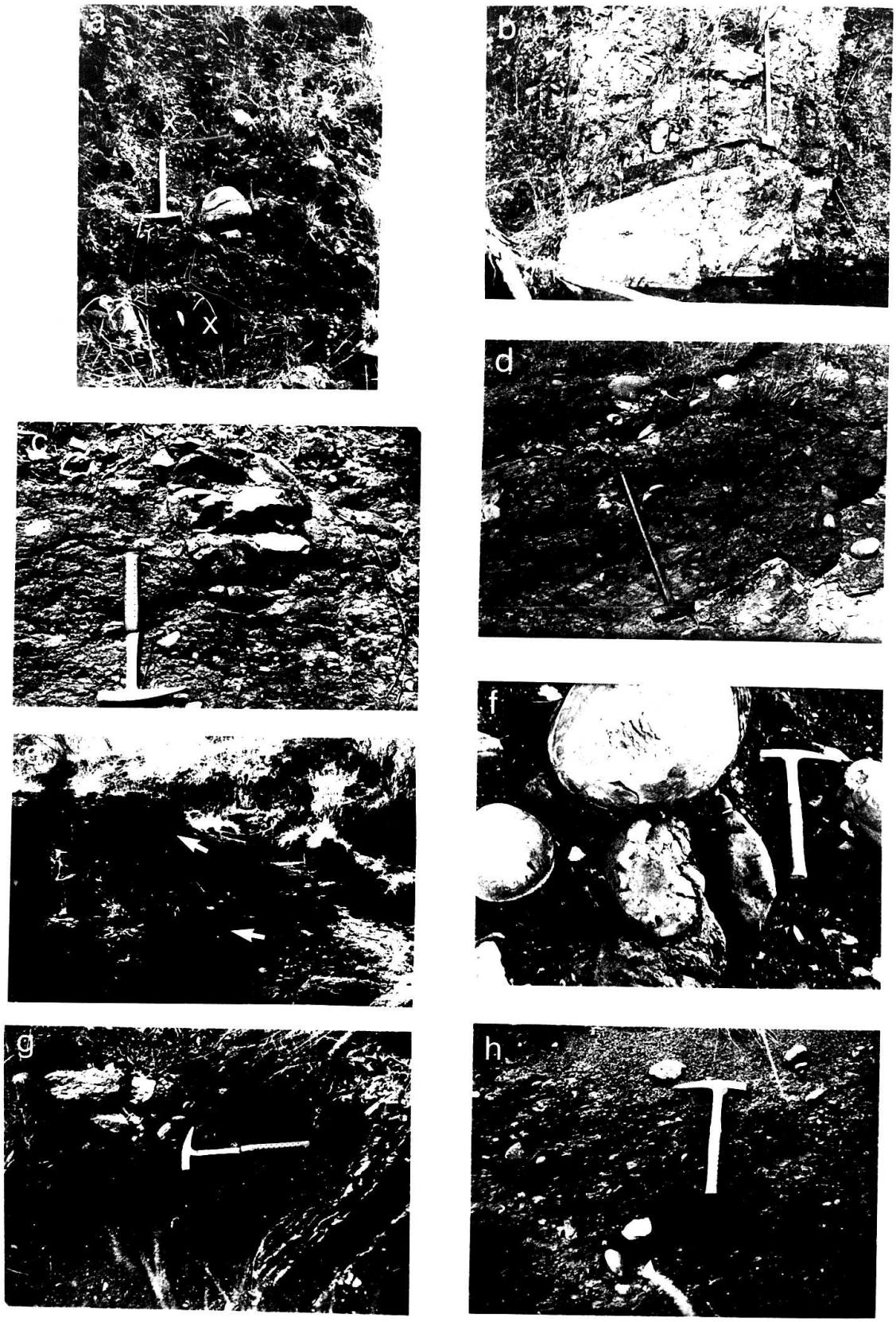

Plate 6.5

reverse grading.*

Normal grading is the most common (43%, 24 of 56 beds) and occurs in all grades from pebble to pebble-cobble-boulder conglomerates (Plate 6.4e). In a few instances (Plate 6.4g) pebble or pebble-cobble conglomerate may grade up to a pebbly coarse to very coarse sandstone. Inverse (Plate 6.4g) and reverse grading commonly occur in pebble-cobble and pebble-cobble-boulder conglomerates, and only occasionally in the associated pebble conglomerates (e.g. MS5). Inverse to normal grading occurs in 20% (11 of 56 beds) and inverse to massive in 25% (14 of 56 beds) of the graded conglomerates. Reverse grading, more common in the pebble-cobble-boulder conglomerates, occurs in 12% (7 of 56 beds) of the graded conglomerate beds.

The graded conglomerates occur predominantly as very thick beds (up to 9.5 metres, an inverse to normal graded bed, 154m, MS38), though may occasionally be medium bedded (minimum 27cm, an inverse to massive graded bed, 19m, MS5). Internal stratification, indicated by fluctuations in clast size, may be present but is by no means common.

Imbrication can be noted in the graded conglomerates in suitable outcrop faces. In one inverse to normal graded bed (MS5, 19.5m) clast A axes were observed to be aligned parallel to the flow direction as inferred from sole marks on the overlying sandstones. Fabric studies upon graded conglomerates (Chapter 4) indicated the presence of imbrication and a preferred A axis orientation parallel and/or perpendicular to flow direction.

Mudstone clasts are present within some graded coarse conglomerates. These graded conglomerates characteristically occur in association with the massive coarse conglomerates (Facies E1) in thick sequences, but occasionally occur as solitary beds associated with the graded sandstones facies (e.g., MS39, MS40).

3. Facies F Matrix Supported Coarse Conglomerates:

The matrix supported coarse conglomerates are far less plentiful than the clast supported coarse conglomerates. They occur interbedded with the latter in thick sequences (e.g., MS8, MS9, MS21), or associated

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*For definitions of these four types of grading, see p. 14.

with facies J graded sandstones, facies K sandstones, facies M interbedded mudstone-sandstone or facies N massive mudstones (e.g., MS3, MS5, MS10, MS19). In one instance, MS3, they occur as channel fill deposits (p.149).

Textures: The matrix supported conglomerates are essentially of pebble-cobble grade with occasional boulders. The matrix varies from a clean to a muddy medium to very coarse sandstone (Plate 6.5c,d). Lateral variation from a dispersed framework with a muddy sandstone matrix to a more continuous framework with a sandy matrix was noted in a matrix supported conglomerate from MS10, 16.5m). A matrix supported coarse conglomerate immediately north of MS9 appears to grade laterally to the enclosing clast supported coarse conglomerates.

Fabric study of matrix supported coarse conglomerates (Chapter 4) showed the clasts to be imbricate upcurrent and the A axes to be oriented mainly transverse to flow direction.

Reworked fossil fragments, including plant debris with some recognisable *Leptophloeum australe*, and abraded crinoid, brachiopod, coral and gastropod fragments are present within the conglomerate matrices in MS3 and MS10.

Structures: The matrix supported conglomerates lack obvious structures. No internal stratification, either horizontal or inclined, was observed. Grading was seen in two matrix supported conglomerates. In MS3 normal grading is present as an upward decrease in both clast size and clast content. The grading is not everywhere perfectly developed, with a 60cm boulder occurring near the top of the bed. In MS10 grading occurs as an upward coarsening then fining of clast size.

Angular mudstone fragments of all sizes up to 15 x 13 x 4 metres (MS3) (Plate 6.5c) occur within these conglomerates in MS3, MS5, MS9, MS10. These fragments are usually of random orientation. The smaller fragments may be contorted, but the larger blocks are generally undeformed. The size and angularity of these blocks suggest they are of local derivation (p.151).

A variant of the matrix supported conglomerates occurs in sections MS21, MS19, MS9, and at locality D (Fig. 2.2). This variant is usually a massive very thick bedded (≥ 4 metres, MS21) pebbly very coarse sandstone

to dispersed framework pebble conglomerate containing plentiful dispersed large cobbles and boulders. Rounded boulders up to 100 cm (MS19) and 115 cm (loc.D) are frequent. Clusters of the large clasts lead to occasional patches of continuous framework within these conglomerates. Grading of the matrix from pebble conglomerate to pebbly sandstone, with the large clasts concentrated in the centre of the unit, occurs in one instance (MS21). Occasional large laminated mudstone blocks (in the order of 1m) may be present (MS19).

3. Facies G Diamictites

Diamictites are rare, occurring only in MS14, where the bed exceeds 12 metres thick, at locality A (Fig. 2.2) and immediately above MS5. Rounded pebbles and small cobbles occur dispersed through an abundant (≥90%) mudstone matrix (Plate 6.5h). The diamictite above MS5 exhibits a preferred orientation of the A' axis (f13-5, Fig. 4.2), assumed to be parallel to flow direction.

The first two localities possess evidence of an earlier, now deformed stratification within the mudstone matrix. Very thin beds of sandstone to in excess of 1 metre long and exhibiting variable degrees of contortion, may be seen in MS14 (Plate 6.5g). In both of these instances the diamictite passes up to laminated mudstones with minor thin sandstones.

The relationship of the diamictite to the associated lithologies is evident in MS14. A lateral gradation exists between the diamictite and a pebbly very coarse lithofeldspathic sandstone, via (1) an interval of diamictite with plentiful medium to very coarse detrital feldspar and (2) a pebbly sandstone with many patches of mud. The diamictite stratigraphically above MS5 occurs as a distinct thick bed conformable within a mudstone dominant sequence.

4. Facies H Graded Pebble Conglomerates

This distinctive facies is considered separate from the less common thinner bedded clast supported pebble conglomerates of facies E2, on the basis of greater bed thickness, the occurrence of both continuous and dispersed frameworks within the one bed, and the almost exclusive association with the graded pebbly sandstone facies.

Individual beds are usually very thick (up to 7 metres at Klori Trig.) and tend to occur associated with the graded pebbly sandstones facies I, with little or no interbedded finer grained sediments. If such are present they are usually of the interbedded mudstone-sandstone facies M. These graded pebble conglomerates are only rarely associated with sequences of the clast supported coarse conglomerate facies E1 and E2, one instance being in MS38.

Textures: The conglomerates are predominantly of pebble grade with occasional cobbles and rare boulders (Plate 6.7a). Boulders up to 175 cm (MS11, 20m) have been recorded, usually occurring as isolated clasts within the pebble conglomerate. Their positioning within a bed is variable, e.g., in one instance a 68 cm boulder occurs in pebbly very coarse sandstone 50 cm from the top of a 5 metre thick pebble conglomerate bed (MS39, 199m). The framework of the pebbles and coarser clasts may be either continuous or dispersed (Plate 6.6a,b), both often occurring within one bed (e.g., a clast supported conglomerate may pass up to a matrix supported conglomerate). The matrices of these conglomerates are clean usually coarse grained sandstone. The clasts range from subangular to rounded (Powers, 1953) with the smaller often being the more angular.

Structures: All units exhibit normal grading (Plate 6.6c), by either a decrease in clast size (e.g., pebble-small cobble conglomerate grading to very small pebble conglomerate) or a decrease in clast percentage (pebble conglomerate grading to pebbly coarse sandstone i.e. coarse-tail grading). Grading often involves a decrease in both clast size and percentage (e.g., a continuous framework pebble-small cobble conglomerate grades to a dispersed framework small pebble conglomerate). In some instances the pebble conglomerates grade up to a coarse grained sandstone.

Inverse grading is developed but is not common. When present, it involves an upward coarsening either from coarse sandstone to pebble conglomerate or from small pebble to large pebble conglomerate (Plate 6.6d). Such usually occurs over an interval of some 5-20 cm. In some instances the degree of development of the inverse grading varies laterally (MS39, 203m).

Crude parallel stratification occurs within some conglomerates (Plate 6.6c,d). Such is usually defined by fluctuations in pebble size,

Plate 6.6

a. Facies H graded pebble conglomerates showing dispersed nature of framework at the base of a bed. Note the amalgamated appearance of the contact between the sandy top of the underlying bed, and the pebble conglomerate. Klori Trig.

b. Facies H graded pebble conglomerates showing the continuous nature of the framework. Klori Trig.

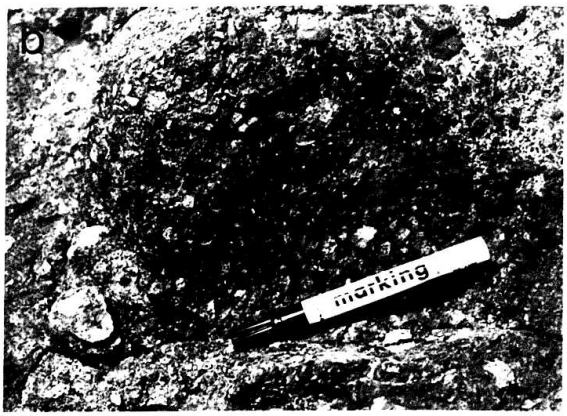
c. Outcrop of graded-stratified model facies H graded pebble conglomerates.

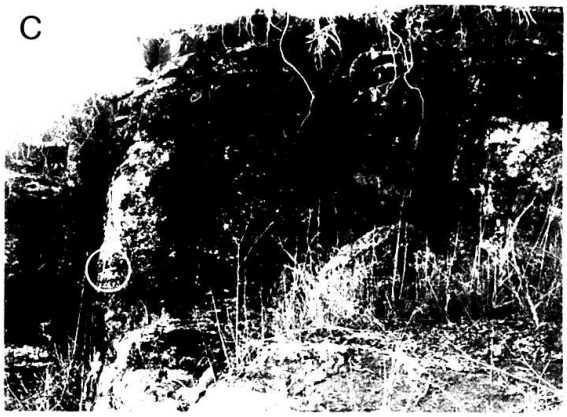
d. Inverse grading in facies H graded pebble conglomerates. Klori Trig.

e. Detail of the stratified upper portion of the graded-stratified facies H graded pebble conglomerate in 6.6c.

f. Detail of basal portion of the graded-stratified facies H graded pebble conglomerate in 6.6c. Note the more continuous nature of the framework compared to that of the upper portion of the bed.

g. Randomly oriented intraformational mudstone blocks in a facies H graded pebble conglomerate. Klori Trig.





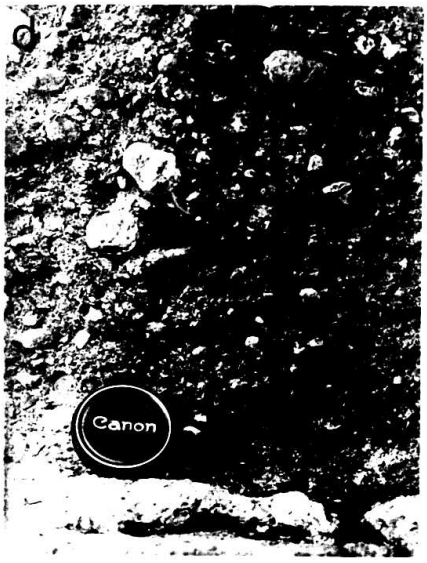


Plate 6.6

Plate 6.7

a. Facies H graded pebble conglomerate possessing large intraformational mudstone clast (a) and volcanic boulder (b). Klori Trig.

b. Detail of basal contact of facies H graded pebble conglomerate over the coarse sandy top of a facies I graded pebbly sandstone. Klori Trig.

c. Facies I graded pebbly sandstone, with plentiful pebbles in the basal portion. Klori Trig.

d. Outcrop of two facies H graded pebble conglomerates with an intervening facies L massive sandstone (L) MS13.

e. Facies I graded pebbly sandstone. Hammer handle is 50 cm. long. MS4.

f. Inverse grading at the base (arrowed) of a facies I graded pebbly sandstone bed, overlying another graded pebbly sandstone. MS39.

g. Outcrop of facies I graded pebbly sandstone with numerous intraformational mudstone clasts. Scale is 60 cm. long. MS39.

h. Detail of intraformational clast from bed in 6.7g. Note sandstone injecting along lamination plane. MS39.

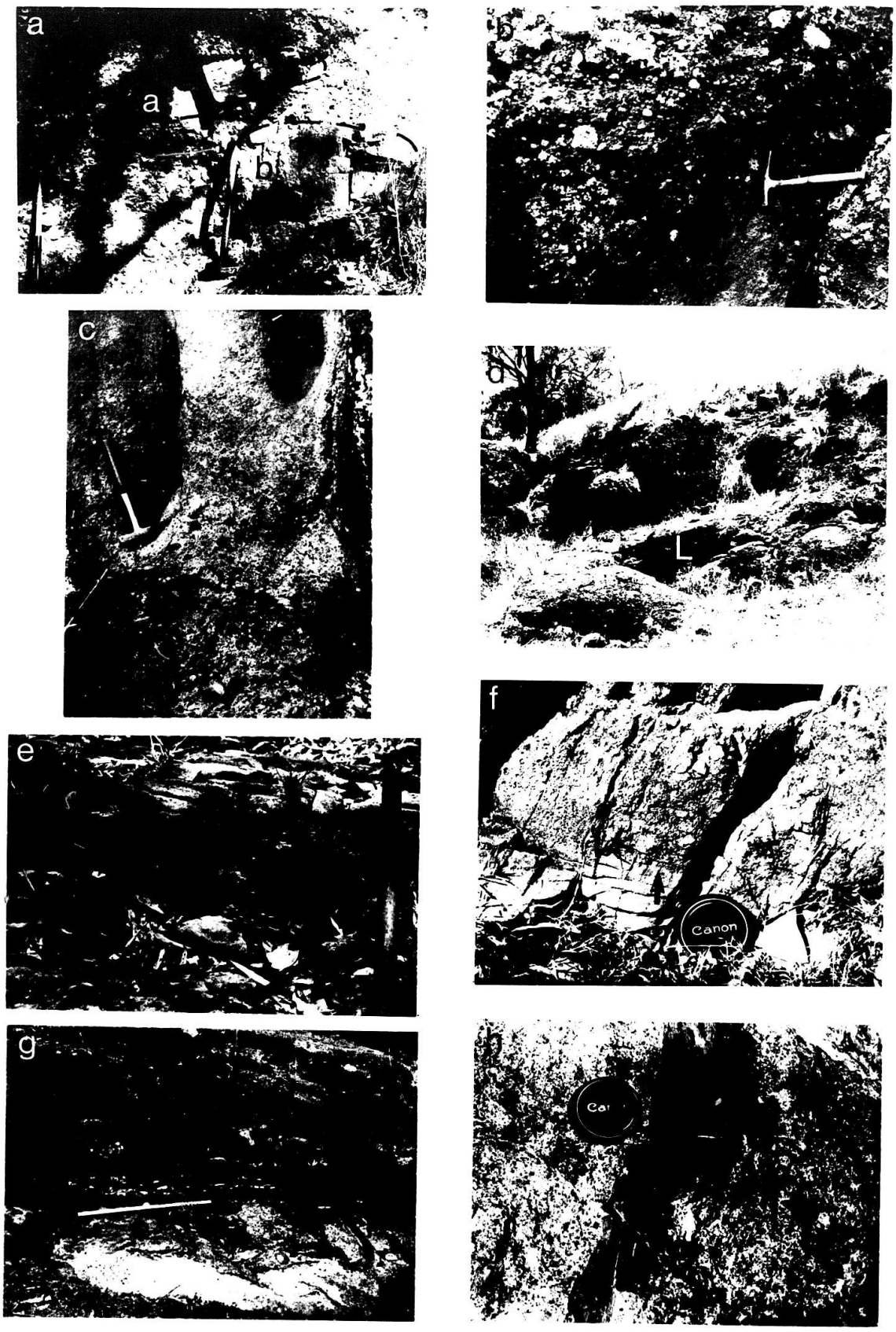


Plate 6.7

or alternation of pebbly and sandy layers. The stratification is on the scale of a few centimetres or less, may possess indistinct boundaries and is often not laterally extensive. When sandstone occurs as the top portion of these pebble conglomerate units it frequently exhibits a crude parallel parting considered to reflect a parallel lamination (e.g., MS39, 205.5m). No cross stratification was observed within the conglomerates.

Fabric studies were not attempted upon these pebble conglomerates. However, imbrication of clasts was noted in a few instances (e.g., MS18) while in other cases platy clasts were observed to be oriented parallel to the stratification. Tabular intraformational mudstone clasts present in some beds show variable orientation, being parallel to, perpendicular to and inclined to the bedding (Plate 6.6g,6.7a).

Intraformational clasts, both mudstone and shale, occur in a number of the pebble conglomerate units (Plate 6.6g,6.7a). They are usually tabular, range in size up to at least 100 cm and rarely show signs of deformation.

Sole markings are rarely observed, probably due mainly to the low frequency of exposure of basal contacts. Small tool casts and flute casts have been observed (e.g., MS20, 34m). Unequivocal scouring at the base of a pebble conglomerate unit was seen in only one exposure (MS11, 36.5m). However, the presence of intraformational fragments clearly shows the erosive potential of the currents which deposited the sediment. In general the basal contacts appear to be planar and conformable upon either conglomerate or sandstone of the previous unit (Plate 6.7b), or upon thin bedded fine grained sediments.

Several thick bedded pebble conglomerates differ to those described above (e.g., in MS4, MS13, MS39). They usually consist of a continuous framework of pebbles, with occasional cobbles, which quickly grades up via a pebbly coarse to very coarse sandstone to a parallel laminated medium (rarely fine) sandstone. In some instances this is overlain by mudstone. Inverse grading is present in some beds, with a basal coarse to very coarse sandstone layer (generally 5 cm to 15 cm thick). The basal contacts where seen are planar and conformable. These beds thus differ to the other pebble conglomerates in being somewhat thinner bedded, in the rapidity of grading from pebble conglomerate to sandstone, and in the finer grades of sediment usually present at the top of the bed. These pebble conglomerates