Submarine carbonate breccia beds—a depositional model for two-layer, sediment gravity flows from the Sekwi Formation (Lower Cambrian), Mackenzie Mountains, Northwest Territories, Canada

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In the Sekwi Formation, carbonate breccia beds interbedded with slope sediments are interpreted as submarine sediment gravity flows that formed a two-layer deposit during a single transport event. They are intermediate between true slumps and turbidites and may initiate by slumping anywhere on the continental slope and rise. Textural characteristics of the deposits are a function of downslope transport distance.

Dans la formation de Sekwi, on interprète les couches de carbonates bréchiques interstratifiés avec des sédiments de talus comme des coulées par gravité de sédiments sousmarins qui ont formé un dépôt bicouche durant un seul épisode de transport. Ces dépôts sont intermédiaires entre les dépôts de glissement véritables et les turbidites et peuvent avoir leur origine dans un glissement n'importe où sur le talus ou la pente continentale. Les caractéristiques texturales des dépôts sont fonction de la distance de transport en aval.

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Introduction

The objective of this paper is threefold. Firstly, to provide a description of carbonate breccia beds that occur within the Lower Cambrian Sekwi Formation; secondly, to offer an interpretation of the origin of these deposits; and finally, to propose a general depositional model for submarine carbonate breccia beds.

Lower Cambrian Slope Sediments

Sedimentary rocks of the Lower Cambrian Sekwi Formation, which crop out in the western and central Mackenzie Mountains of Canada (Fig. 1), define a shelf to slope transition (Fritz 1976*a*, *b*, 1978; Krause and Oldershaw 1977, 1978).

Slope sediments of the Sekwi Formation (Figs. 2, 3) are laminated and bedded siltstones, shales, and locally limestones. Typical sedimentary features of these deposits are graded bedding, bioturbation, soft sediment deformation structures that include slump folding and faulting, load casting, convolute lamination, rotated limestone nodules, and injection structures. Within this fine-grained sequence [illegible] *breccia beds* have been recognized, 35 of which are characteristically two-layer deposits. These breccias derived from the adjacent carbonate shelf and surrounding slope, flowed downslope, and were deposited on top of adjacent slope sediments.

Breccia Beds

The use of the term breccia bed in this paper follows the example of several workers, among them Cook *et al.* (1972) and Hopkins (1977). It is clear that the descriptive usefulness of the term precludes its restriction solely to deposits that originate as sediment gravity flows. However, for the purposes of this paper and in the absence of a better descriptor, a breccia bed is the product of resedimentation mechanisms and possesses the attributes illustrated.

Bedding Style

Breccia beds of the Sekwi Formation typically are 0.3–5 m thick and laterally extensive. Separate flows have been traced laterally for 4 km, and may display marked changes in thickness, pinching, and swelling at irregular intervals (Fig. 3*a*). Bed thickness commonly doubles at swells, although increases of 4 times have also been observed. In two places, where a breccia bed was observed to abut against slope sediments, contacts were blunt and steep. Breccia beds typically exhibit basal unconformable contacts with scouring and commonly deformation of underlying lithologies.

Breccia Clasts

The most striking characteristic of breccia beds is their fragmented clastic texture. Breccia bed clasts are 1–50 cm in size and may be shaped like irregular, indented, angular to subrounded shingles, or as irregular, oblong, and spheroidal fragments. Dominant clast lithology is calcareous mudstone, wackestone, and packstone with cross-

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FIG. 1. Index map of Canada with location of study area. Outlined in black are the Lower Cambrian sediments examined as part of this study. Dashed line indicates position of stratigraphic cross section displayed in Fig. 2.

laminated silt to coarse-grained quartz sand. Locally, rare shelf derived clasts consisting of oolitic grainstone and archeocyathid boundstone are also found. Lithology of the majority of clasts is identical with that of fine-grained sediments of the neighbouring slope from which clasts were derived (Fig. 3*c*). Early lithification of slope sediments is indicated since clasts are fragmented and comminuted. Individual clasts are broken by wedge-shaped cracks and clast edges are commonly angular (Fig. 3*d*).

Internal Structure

Clasts may be arranged in completely disorganized, chaotic, and almost random fabrics, or they may be found in imbricated, aligned, graded, or inverse to normally graded arrangements with coarse tail grading (Fig. 3 *e–h*). Also, breccia beds may be capped by a turbidite which consists of comminuted breccia material (Fig. 3 *b*, *f*, *g*). Presence or absence of this turbidite layer defines two broad types: beds that possess only a coarse clastic interval (X) and beds that possess both a basal clastic interval (X) and a top turbidite interval (Y) (Figs. 3, 4). Interval X comprises clasts in grain and mud support with a matrix of silt, shale, and also comminuted breccia material. Typically a breccia (interval X) is overlain by grainstones (interval Y) of finely fragmented breccia material. A complete Y interval displays grainstones in the following upward progression: massive, poorly graded or ungraded; plane parallel laminated; ripple-drift cross-laminated. These units are identical to the A, B, and C intervals of the Bouma sequence. The contact between breccia and turbidite intervals is commonly scoured, but unscoured transitions have been observed. Scours up to 10 m wide may cut completely through the underlying breccia. Semicircular pockets up to 3 m wide and 1 m high, with material identical to the grainstones in interval Y, may occur within and below the base of breccia interval X.

Breccia Bed Sequences

Following Walker's (1975, 1976) scheme for resedimented conglomerates (see Table 1 for a comparison between breccia beds and resedimented conglomerates), 3 types of breccia beds have been identified in the field. Type 1 beds (Fig. 6) are single-layered and possess clasts in completely disorganized and chaotically oriented fabrics. Clasts may be matrix or grain supported and are enveloped by silty shale. Types 2 and 3 are double-layered breccia beds and may be differentiated by the arrangement of clasts of interval X. Clasts of type 2 beds (Fig. 6) are disorganized, chaotically oriented, grain supported, and most often possess silty shale or mixed silty shale and comminuted breccia matrix. Type 3 beds have clasts that display normal grading and inverse to normal grading. The

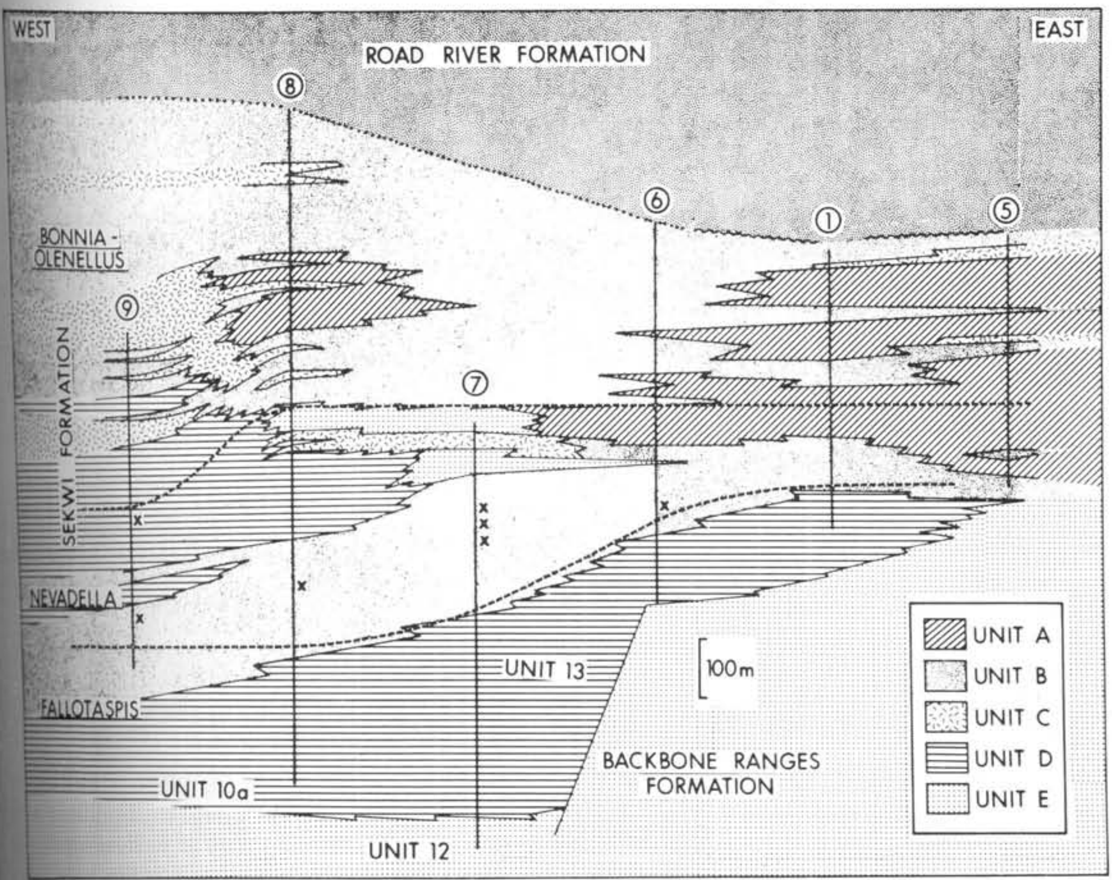

FIG. 2. Schematic stratigraphic cross section through the Sekwi Formation. Sections 5, 1, 6, 7, 8, 9 show informal units A–E that display a shelf and slope transition located by a dashed line on Fig. 1. Units A–E are characterized respectively by supratidal dolostones, subtidal calcareous sedimentary rocks, oolitic carbonates, subtidal shaly silts, and nearshore and coastal plain sandstones (Krause and Oldershaw 1977, 1978). Biostratigraphic framework is based on a detailed analysis of trilobite faunas by Fritz (1972, 1973, 1976*a*, 1978). Breccia bed occurrences are indicated by x.

matrix consists predominantly of grainstone breccia and also of silty shale with comminuted breccia.

Occurrence

Breccia bed occurrences in a transect across the regional strike of the Sekwi Formation are indicated in Fig. 2 and are also tabulated in Table 2. Single-layer breccia beds are restricted to uppermost breccia occurrences at sections 8 and 9 and are the only breccia bed type observed at section 6. Seventeen double-layer type 2 breccia beds (Fig. 6), averaging 30 cm in thickness, were recorded above type 3 beds at section 7; a single type 2 bed was noted between type 3 beds at this section. One type 2 bed, above type 3 and below single-layer beds, was recorded at section 9. Type 3 breccia beds characteristically are the lowermost breccia bed type encountered at sections 7–9. Important to note here is that sections 7–9 are in margin to slope positions (Fig. 2). Different breccia types are reconstructed into a lateral depositional model elsewhere in this paper.

Breccia beds in the Sekwi Formation have been recognized at localities isolated from each other by 200 km. They also occur over a distance of 50 km in traverses across strike (Fig. 2).

Two-layer Sediment Gravity Flow Deposits

Submarine carbonate breccia beds with a capping turbidite are not unique to the Sekwi Formation. Table 3, although not exhaustive, presents references and comments on submarine carbonate breccia beds discussed in the literature and establishes their commonplace occurrence. The existence of sediment gravity flows in which a basal, dense, faster moving flow, with grains supported by dispersive pressure, was overlain by a turbidity

TABLE 1. Main characteristics of breccia beds* and resedimented conglomerates†

Breccia beds	Resedimented conglomerates
1. Semiconsolidated sediment, supplied by slumping and sliding of shelf edge and slope deposits. Resedimentation takes place downslope from slide	1. Unconsolidated sediment pile accumulates in shallow water and is supplied to canyon feeder channel during low stands of sea level and (or) by strong currents on a narrow shelf
2. Clast lithologies mirror shelf edge and slope sources	2. Clast lithologies reflect continental and marine sources
3. Breccia bed material builds its own 'channel'	3. Material travels downslope in pre-existing channels
4. An ideal breccia bed consists of two concurrently deposited layers, a lower clast interval (layer X) and an upper turbidite interval (layer Y). The turbidite may contain A, B, and C beds of the Bouma model	4. A resedimented conglomerate is not usually capped by a turbidite interval. Sedimentary textures throughout the bed may superficially resemble the Bouma sequence
5. Three types of breccia beds have been recognized in the field: Type 1. Consists of a disorganized clast interval without a turbidite cap Type 2. Contains a disorganized basal clast layer and is capped by a turbidite Type 3. The clasts of layer X display normal or inverse to normal grading and are capped by the turbidite of layer Y	5. Four models of resedimented conglomerates have been proposed: Model 1. Disorganized bed Model 2. Beds where clasts are inverse to normally graded Model 3. Bed with clasts that are normally graded Model 4. Deposits where clasts are graded and finer material may be stratified towards the top. This model may superficially resemble the Bouma sequence as both contain a lower massive or graded division and pass upward into horizontal stratification
6. A downslope facies gradation from slumped deposits, to disorganized breccia beds, to normal and inverse-normal graded breccia beds is suggested and may be a function of transport distance	6. Models 2, 3, and 4 may reflect a downchannel facies gradation and may indicate increasing distance of transport

*This paper and literature on modern debris flows, in particular Johnson (1970).
†After Walker (1975, 1976, 1978).

TABLE 2. Breccia bed occurrences, Sekwi Formation

	Number of flows recorded	Single-layer flows	Double-layer flows
Section 6	4	4	0
Section 7	28	0	28
Section 8	9	5	4
Section 9	6	3	3
Total	47	12	35

current, was strongly advocated by Sanders (1965). The occurrence of a flowing-grain layer at the base of a depositing, high density turbidity current was strikingly confirmed by Middleton (1967). His experiments showed a denser basal flow that moved downcurrent by shear of the bed, rather than by rolling and sliding of individual particles. Middleton (1969) proposed that a large scale, high velocity grain flow must produce an entrained layer in the overlying water and cause it to flow rapidly. He suggested further that this entrained layer may scour the top of the underlying bed (grain flow) and rework it. More recently, Hampton (1972) has demonstrated the development of a turbidity current on top of a moving subaqueous debris flow.

Development of a Two-layer Deposit

The origin of double-layer beds may be understood in terms of the modelling experiments on subaqueous debris flows performed by Hampton (1972) (see Fig. 5). He demonstrated that the front of a subaqueous debris flow deformed in response to stresses imposed by the surrounding water. Sediment was eroded along the front of the debris flow

FIG. 3. (*a*) Breccia bed exposed on north facing cirque wall within deep-water sediments of Sekwi Formation. Breccia bed expands and narrows at irregular intervals. A and B arrows point respectively to 'tail' and 'wave' of breccia bed. Similar features have been observed with subaerial debris flows and also in flume experiments with subaqueous flows. Arrow C points to scoured base of breccia bed. Thickness of deposit at 'wave' approximately 12 m. Section 7. (*b*) Breccia bed 4.5 m thick with characteristic double layering. Lower arrow points to breccias of interval X and upper arrow points to grainstones of interval Y (see Fig. 4). Section 9. (*c*) Calciturbidite typical of lithologies encasing breccia beds and commonly found as breccia constituent. Scale 4 cm long. Section 7. (*d*) Breccia bed clasts. Wedge-shaped fractures indicated by arrow A and comminuted breccia material identified by arrow B suggest that clast material was probably lithified prior to flow event. Section 8. (*e*) Disorganized breccia bed. Arrow points to individual clast. Bar 2.7 m long. Section 9. (*f*) Disorganized, stratified breccia bed. Bar 25 cm long. Section 9. (*g*) Transition in a breccia bed from clast interval X to stratified grainstone interval Y. Arrow points to scour at top of breccia interval. Scale 5 cm long. Section 8. (*h*) Inversely graded breccia. Arrow points to base of breccia bed. Bar 25 cm long. Section 7.

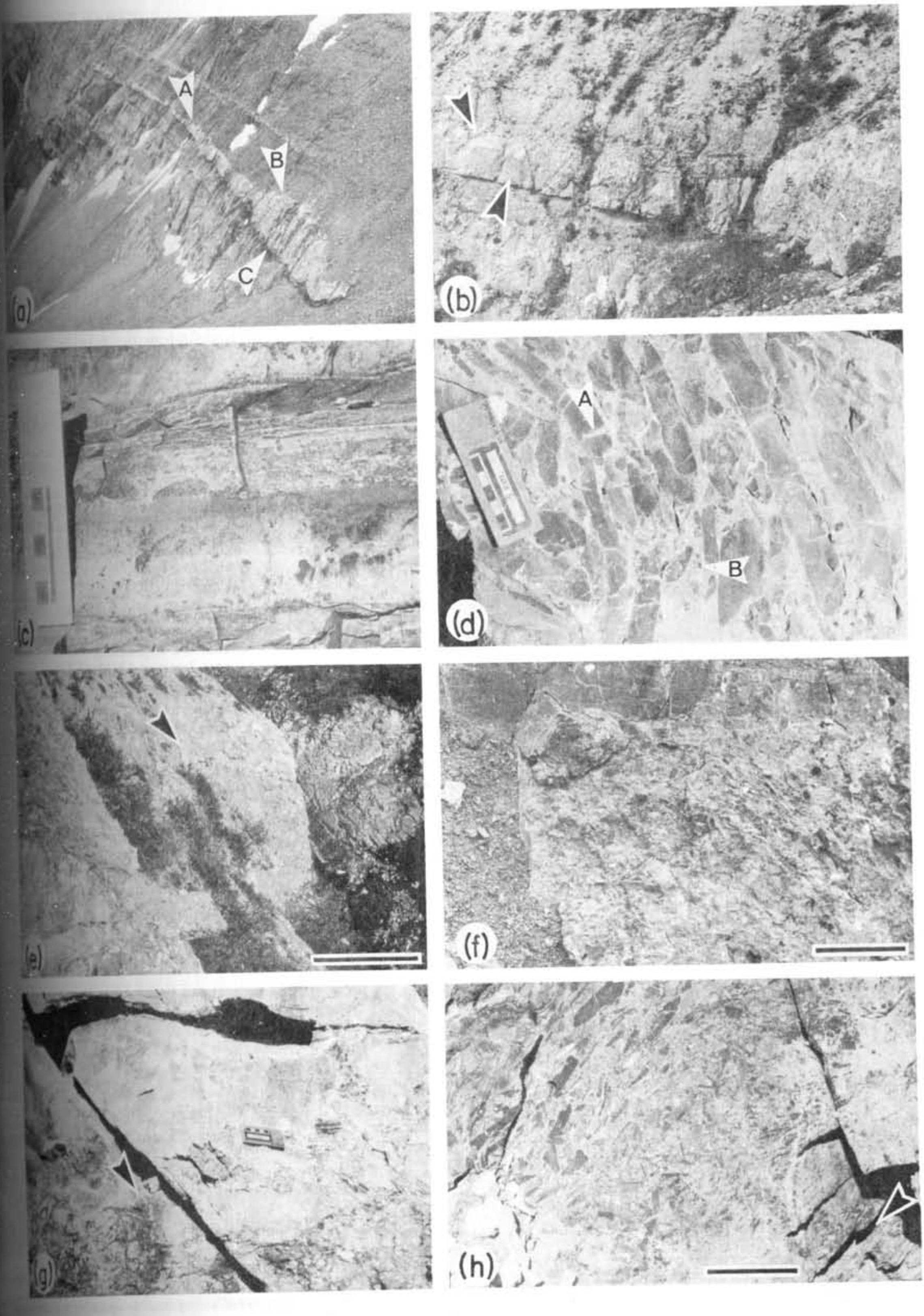
A
B
C
(a)
(b)
(c)
A
B
(d)
(e)
(f)
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TABLE 3. Reported subm

Author	Age	Rock unit	Location	Stratified
Reinhardt (1977)	L. Camb.	Araby and Frederick Limestone Formations	Western Piedmont, Appalachians, U.S.A.	Yes?
Snyder and Odell (1958)	Camb.	Boneterre Formation	Southeast Missouri, U.S.A.	No?
McIlreath (1977)	M. Camb.	Boundary Limestone	Field, B.C., Canada	No
Cook and Taylor (1977)	U. Camb. L. Ord.	Hales Limestone	Hot Creek Range, Nevada, U.S.A.	Yes
Hubert *et al.* (1977)	M. Camb. M. Ord.	Cow Head Breccia	Newfoundland, Canada	Yes
Winterer and Murphy (1960)	Sil.– L. Dev.	Lone Mountain Dolomite and Roberts Mountain Formation	Roberts Mountains, western Nevada, U.S.A.	Yes?
Conaghan *et al.* (1976)	L. Dev.	Nubrigyn Formation	New South Wales, Australia	Yes
Playford and Lowry (1966)	Dev.	Napier Formation	Canning Basin, Western Australia	No
Hopkins (1977)	U. Dev.	Miette and Ancient Wall buildups	Rocky Mountains, Alberta, Canada	Yes
Cook *et al.* (1972)	U. Dev.	Ancient Wall buildup	Rocky Mountains, Alberta, Canada	Yes
Thomson and Thomasson (1969)	L. Penn.	Dimple Limestone	Marathon region, Texas, U.S.A.	Yes
Davies (1977)	Penn. Perm.	Hare Fiord Formation	Sverdrup Basin, Canadian Arctic	?
Thomson and Thomasson (1962)	Perm.	Kriz Lens	Sierra Diablo, Texas, U.S.A.	?
Newell *et al.* (1953)	Perm.	Bell Canyon Formation	Guadalupe Mountains, west Texas and NM, U.S.A.	Yes
Jacka *et al.* (1968)	Perm.	Delaware Mountain Group	Guadalupe Mountains, west Texas and NM, U.S.A.	Yes
Dunham (1972)	Perm.	Bell Canyon Formation	Guadalupe Mountains, west Texas, and NM, U.S.A.	Yes
Price (1977)	U. Trias. L. Cret.	Gavriana and Meterizia Formations	Othris, Greece	Yes
Hendry (1972)	L. Jur.	Lower Breccia Formation	French Pre-Alps	Yes
Finger (1975)	M. Jur.	Bardella Formation	Graubunden, Switzerland	Yes
Garrison and Fischer (1969)	Jur.	Adnet Bed and Ruhpolding Radiolarite	Northern Limestone, Alps, Austria	?
Schlager and Schlager (1970)	U. Jur.	Tauglboden Schichten	Eastern Alps, Austria	Yes
Remane (1970)	U. Jur.– L. Cret.	Vocontian Trough	Subalpine ranges, southeastern France	Yes
Baldomero Carrasco (1977)	Cret.	Upper Tamaulipas–Tamabra Limestone	Sierra Madre, Oriental, Mexico	Yes
Enos (1977)	Cret.	Tamabra Limestone	Tampico Embayment, Mexico	?
Van Hoorn (1969)	U. Cret.	Campo Breccia Formation	Southcentral Pyrenees, Spain	Yes
Pszczolkowski (1978)	U. Cret.– L. Eoc.	Buena Vista and Ancon Formations	Cordillera de Güanigüanico, western Cuba	Yes?
Renz *et al.* (1955)	Paleoc.– Eoc.	Paraguito Boulder Bed	Lara, Venezuela	Yes?

NOTES: Descriptions and figures in these publications indicate that many breccias have a capping turbidite component. Interpretation of deposits

...breccia bed occurrences

...source	Bed type	Comments
...and slope	Disorganized predominates. Also graded and inversely graded	Some beds amalgamated. Individual bed thickness variable
...	?	Tongue shaped in plan view. Individual bed thickness variable. Amalgamation of some beds. Commercial lead–zinc mineralization in matrix of several beds
...	Disorganized	
...and slope	Disorganized and normally graded, both types with stratified caps	Some beds with only slope-derived clasts
...and slope, ...slope	Disorganized and normally graded	Some beds may amalgamate. Internal shear surfaces and scoured bases
...and slope	Normally graded	Individual beds variable in thickness. Mud-supported clasts and clast-supported framework with grainstone matrix
...and slope, ...predominant	Disorganized predominates. Also graded with stratified caps	Sheet and lense-like deposits
...and slope	Disorganized	Clast-supported framework. Surrounding lithologies deformed and scoured
...and slope	Predominantly disorganized	Some beds capped by calcarenites which may be discontinuous
...and slope	Seemingly disorganized, locally inversely graded	Individual beds variable in thickness. Channeling apparent
...and slope and ...mations other ...the Dimple Ls.	Nongraded (disorganized?). Partially graded (disorganized?). Graded, capped by partial Bouma Sequence	Large trough cross-stratification in some beds
...and slope	Disorganized	Individual bed thickness variable, lenticular, and mound-like in profile. Sheet-like along strike traced 18 km
...minantly ...shelf-derived	?	Mud content increases towards base of flow. Abrupt change in thickness from 40–1.5 m in 450 m
...and slope	Disorganized and graded	Individual bed variable in thickness. Blunt-edged terminus in one slide in Rader member. Disorganized to graded transition over 5 km
...and slope	Nongraded (disorganized?). Normally and inversely graded	Individual beds variable in thickness. Downcurrent change in clasts from chaotic to aligned
...and slope	Disorganized(?) to graded(?). Units capped by turbidites	Clasts indurated prior to transport. Grading better developed in basinal deposits
?	Predominantly graded, inverse and normally	Change into overlying turbidite gradual. Double layer develops as flow moves downslope
?	Ungraded (disorganized?) and graded. Stratified caps on graded breccias	Thickness of individual bed variable. Large tabular and trough cross-stratification
...lop?	Graded breccia, also disorganized with matrix-supported clasts	Individual bed thickness variable
...and slope, ...dominant	Slump-rubble bed (disorganized?). Also graded	Figure 16 disaggregation of a slump into rubble along hinges of slump folds
...lope	?	Beds tongue-shaped in outline. Grain size of breccia material decreases away from source. Beds may amalgamate
...and slope, ...majority from ...lope	Disorganized matrix-supported. Disorganized with matrix and clast supported framework and calcarenite caps. Graded with calcarenite caps; abrupt or gradual transitions	Early induration of clasts indicated by wedge-shaped cracks infilled with spar and mud. Flows may show amalgamation. Individual bed thickness variable over short distances. Figure 10 illustrates association between underlying disorganized breccia and overlying turbidite ('microbreccia')
...and minor ...amount from slope	Disorganized. Normally graded with overlying turbidite	Matrix and clast supported frameworks
...and slope	?	Oil production from breccia beds in Poza Rica Trend. Matrix and clast supported frameworks
...seemingly derived from ...formations	Ungraded (disorganized?), graded and graded with transition to Bouma interval	Downslope gradation of breccia types from ungraded to graded
...and slope	Normally graded, possibly capped by turbidites	
...and slope	Graded	

...is our own and is not necessarily the opinion of the listed authors.

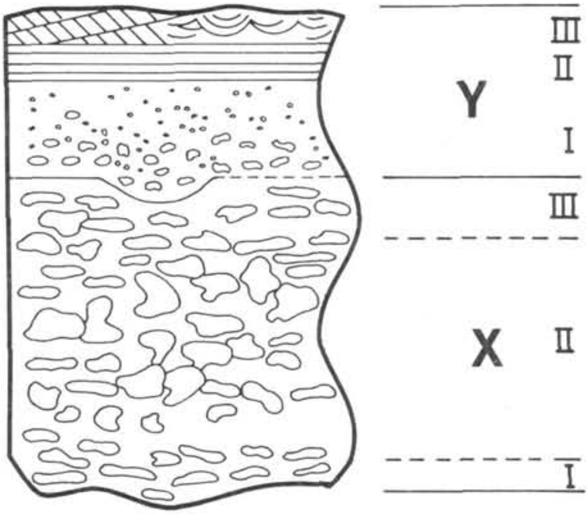

FIG. 4. Idealized breccia bed with a lower breccia interval (X) and an upper grainstone turbidite interval (Y). Interval X is characterized by: (1) large clasts commonly grain supported and, less frequently so, matrix supported; (2) matrix of clay or fine-fragmented clast material; (3) clasts ungraded or displaying coarse tail and composition grading; (4) clasts aligned, imbricated, or completely disorganized; (5) shear zones at top and base of some flows (X_I and X_{III}); (6) a scoured base or rarely amalgamation with underlying material; also, beds beneath breccia may be deformed; and (7) channel-like deposits of grainstone material from interval Y within and along base of bed. Interval Y is characterized by grainstones in following downward progressing sequence: (1) ripple-drift cross laminations (Y_{III}); (2) plane parallel laminations (Y_{II}); (3) massive poorly graded or ungraded (Y_I); and (4) abrupt size transition into underlying breccia and (or) well-developed scour surface.

by reverse shear to a point where it was abruptly thrown into turbulent suspension. Hampton (1972, pp. 785–788, Figs. 12, 13) suggests that the pressure distribution around the front of a debris flow explains the mixing mechanism. In the area of reverse shear, near the front edge of the flow, pressure is large enough to hold material to the debris flow surface. A low pressure zone exists near the nose of the flow behind the layer of reverse shear, where the flow direction of fluid along the surface of the debris flow is opposite to that in the layer of reverse shear. Material in the layer of reverse shear moves continuously into the region of low pressure, where it is lifted away from the debris flow surface into the overlying turbulent region. The cloud that develops in this mixing process is a turbidity current.

The two-layer Sekwi beds can be explained in terms of Hampton's experiments. Caps on breccia beds would be the result of a turbidity current that developed on top of a moving carbonate mass as material along the front of the flow was sheared backwards into the low pressure zone and lifted into the overlying turbulent region. Grainstone deposits within and below some breccia beds of the Sekwi Formation would develop during transport as the overlying turbidity current scoured the top of the underlying flow, and as portions of the turbid cloud spilled over the sides of the main body of flow to scour the surrounding slope and plain sediments. Ultimately, grainstones in scoured pockets would be trapped by oncoming and expanding surges of the denser flow.

A Depositional Model for Submarine Carbonate Breccias

Breccia bed occurrences in the Sekwi Formation, identified in a traverse across regional strike (Fig. 2), indicate that single-layer breccia beds are concentrated in upper parts of sections measured and that both normally and inversely to normally graded breccia beds are concentrated in the lowest. Breccia beds may be arranged in a depositional sequence which suggests a downslope gradation of breccia bed types (Figs. 6, 7).

The Model

With increasing transport there is a downslope transition from slumped deposits, to disorganized flows, to normal and inverse-normal graded flows. Sediment masses generated during slumps resediment further downslope and leave the following sequence: (1) *disorganized bed*: breccia clasts are disordered and matrix or grain supported; (2) *disorganized stratified bed*: with matrix or grain supported breccia clasts overlain by massive, parallel laminated grainstones of comminuted breccia material; and (3) *graded (normal or inverse) stratified bed*: normal to inverse-normal grain supported clasts are overlain by a grainstone turbidite of comminuted breccia material.

It is suggested here, that breccia beds are initiated from slumps, a concept also advocated by Hopkins (1977), Cook (1978), Abbate *et al*. (1970), and others. It is also suggested here, that downslope movement of large sediment gravity flows, initiated from slumps, may occur in locations other than submarine canyons and feeder channels, a view which is supported by the occurrence of laterally extensive breccia beds in the Sekwi Formation, and by previously published work on breccia beds with similar characteristics (Hopkins 1977; Cook and Taylor 1977; Hubert *et al*. 1977; Abbate *et al*. 1970), in addition to recently published accounts of very large slumps on modern continental margins (e.g., Embley 1976; Dingle 1977; Moore *et al*. 1976).

Conclusions

Carbonate breccia beds of the Sekwi Formation

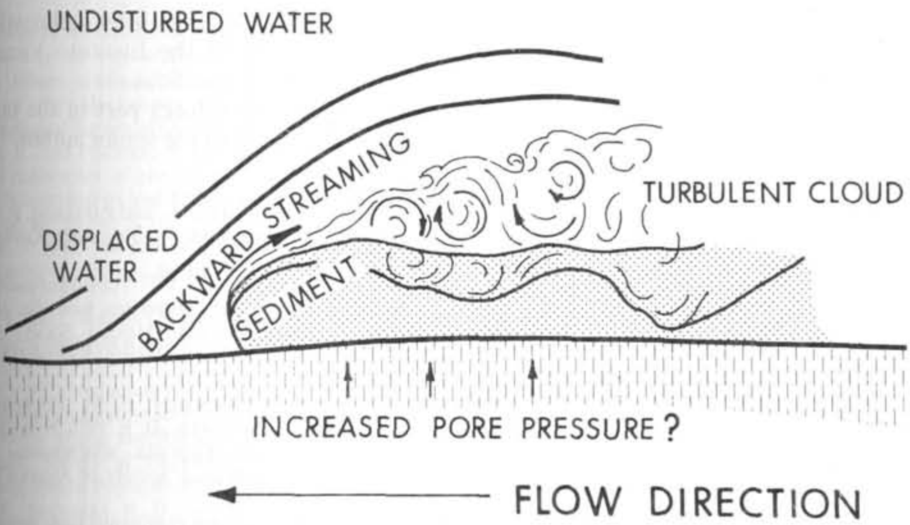

FIG. 5. Diagram illustrates some of the observations made by Hampton (1972) during flume studies with subaqueous clay slurries. Breccia beds may develop two distinct zones (see Fig. 4) as a result of turbidity currents that develop on top of the main mass of the sediment gravity flow.

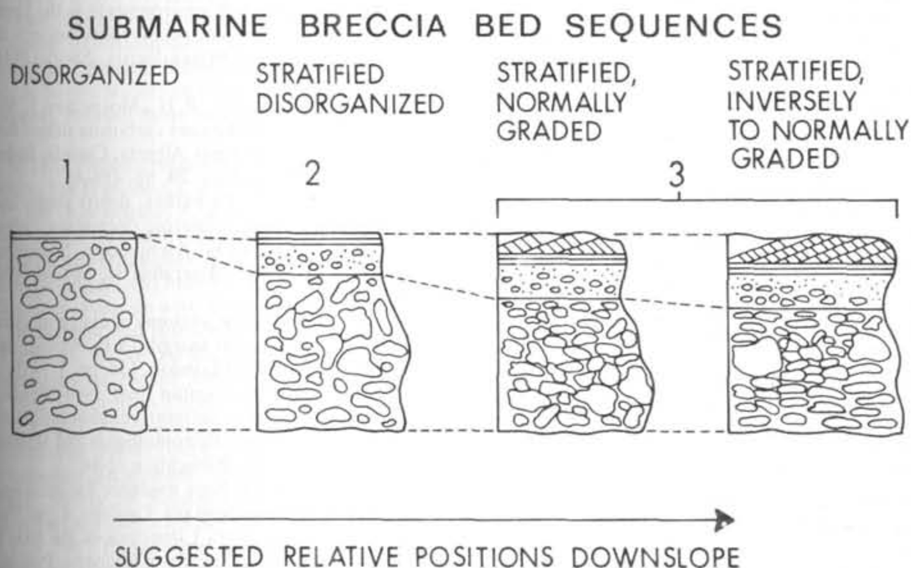

FIG. 6. Breccia bed types observed in the field: (1) disorganized bed—breccia clasts are disordered and matrix or grain supported; (2) disorganized, stratified bed—disordered breccia clasts, matrix or grain supported, and overlain by massive and parallel laminated grainstones of fragmented breccia material; and (3) normally or inversely-normally graded, stratified beds—breccia clasts are normally or inversely to normally graded, matrix consists predominantly of comminuted breccia material, and beds are capped by a turbidite with Bouma A, B, C intervals.

are submarine sediment gravity flows that represent resedimentation episodes. Most of these deposits are two-layer systems that develop during a single transport event. The deposit may consist of a brecciated interval with or without a capping turbidite interval. Transport and resedimentation downslope of breccia beds may take place anywhere on the continental slope and rise, and is not restricted to submarine canyons.

Clasts in a breccia bed are commonly grain supported, pebble to boulder sized calcareous wackestones and mudstones. Each breccia bed is characterized by one of the following clast fabrics: disorganized (types 1, 2), normally graded, or in-

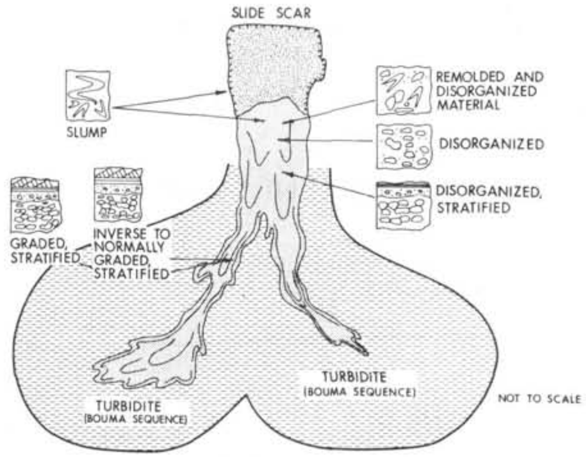

FIG. 7. Suggested submarine sediment gravity flow model for carbonate breccia bed deposits observed in the field. Observations of subaerial debris flows (Johnson 1970), published examples of carbonate breccia beds, and examination of sections through breccia beds of the Sekwi Formation indicate the probable geometry of these deposits (Newell *et al.* 1953; Snyder and Odell 1958; Thomson and Thomasson 1962; Schlager and Schlager 1970; Cook *et al.* 1972; Playford 1977). Breccia beds are irregular in shape, sheet and tongue-shaped in plan view, lenticular in frontal section, and possess pinch and swell topography in longitudinal section. The process is initiated by slumping and sliding of slope deposits (calciturbidites). Material flows as a liquefied slurry, disaggregates, and remolds; a deposit of disoriented clasts is produced. Continued downslope movement of the undrained sediment gravity flow and mixing with the overlying water mass produces a turbidity current on top of the flow; the deposits consist of a basal clast interval with a turbidite on top and a depositional sequence as suggested for Fig. 6. The turbidity current races away from the basal portion of the flow as the latter comes to a stop. A turbidite lacking a breccia bed component will blanket the surrounding sea floor.

versely to normally graded (type 3). Textural characteristics of these deposits appear to be a function of transport distance. With increasing transport there is a downslope transition from slumped deposits, to disorganized, to normal and inverse-normal graded deposits.

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