PRELIMINARY CLASSIFICATION OF CARBONATE BRECCIAS, NEWFOUNDLAND ZINC MINES, DANIEL'S HARBOUR, NEWFOUNDLAND

by

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Abstract

Zinc ore at Newfoundland Zinc Mines is strata-bound in dolostone within the upper third of the Lower Ordovician Catoche Formation (St. George Group) of the Humber Zone in western Newfoundland. Five types of breccias associated with zinc ore are distinguished in a preliminary classification.

Intraformational breccias, strata-bound units of the Aguathuna Formation, represent disconformities or early diagenetic dissolution surfaces associated with the transition from subtidal to supratidal lithofacies. Fine rock matrix breccias associated with pre-Middle Ordovician structural depressions are divided into two types: oligomictic breccias formed by strata-bound dissolution, and polymictic breccias accumulated in vertical dilation openings along the margins of structural depressions. White spar breccias that host the zinc ore are characterized by open fracture and cavity systems filled with megacrystalline white dolomite. True spar breccias occur where strata are broken by faulting, veining or dissolution. Elsewhere, pseudobreccia represents in situ *replacement by white dolomite.*

Introduction

Zinc ore deposits of Newfoundland Zinc Mines, Daniel's Harbour, are hosted in dolostone of the upper St. George Group (Lower Ordovician) in western Newfoundland (Figure 1). Several types of breccias are related to zinc ore as both gangue and associated rocks, but their nature and interrelationships are poorly understood. The genesis of the breccias is directly related to the origin of the zinc ore of this and other Mississippi Valley type deposits. A preliminary classification of breccias and their relationship to zinc ore is presented as a first step towards understanding this genesis.

This study is an extension of previous studies carried out at the site. Collins (1971) and Collins and Smith (1975) recognized a variety of features that suggested ground preparation by karst. Dillon (1978) analyzed the rock geochemistry. Coron (1982) studied ore genesis from host rock petrography and isotope geochemistry, and developed models for ground preparation by evaporite dissolution, and generation of ore fluids along faults.

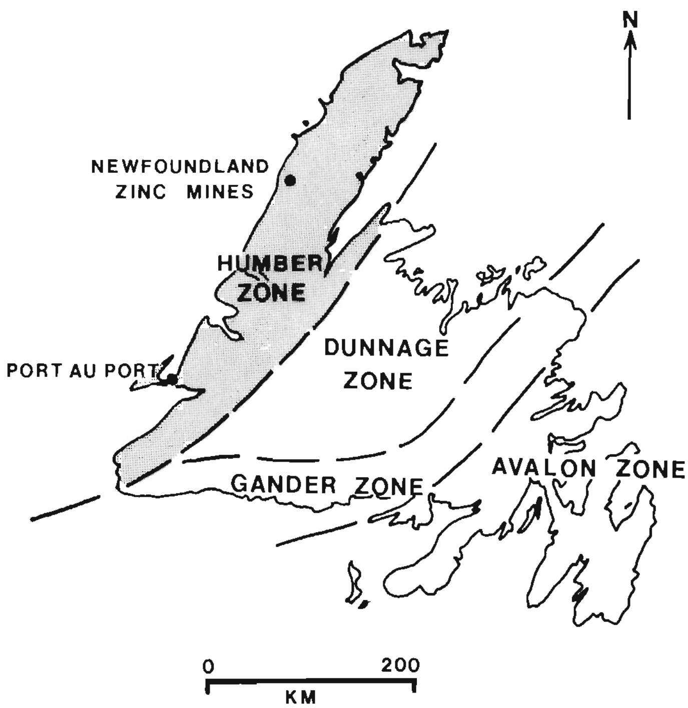

Figure 1: *Tectonostratigraphic zones of Newfoundland with the location of Newfoundland Zinc Mines (after Williams, 1979).*

Regional Geology

The Daniel's Harbour deposit is located within autochthonous rocks in the

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Humber tectonostratigraphic zone (Williams, 1979), which is interpreted to be the ancient continental margin of North America on the western margin of the Cambro-Ordovician Iapetus Ocean (Figure 1). A Lower Cambrian to Lower Ordovician succession of shallow water siliciclastic and carbonate rocks overlie Precambrian Grenville basement. The autochthonous rocks are partly covered by easterly derived thrust slices of deep marine strata and ophiolites, which were emplaced during the Taconic Orogeny (Middle Ordovician). The autochthonous rocks are relatively undeformed and unmetamorphosed. However, some strata are displaced up to 1500 m by faults striking 020° to 060°, and tilted into a series of westerly dipping monoclines along these faults.

A stable shallow marine platform existed in the Humber Zone from Early Cambrian through Early Ordovician time (Knight, 1977; Levesque, 1977; Pratt, 1979; James and Stevens, 1982). During the late Precambrian - Early Cambrian, the North American continental margin became an area of sediment accumulation following postrift downwarping. By Middle Cambrian time, an extensive shallow water carbonate platform had been established. Middle to Upper Cambrian formations (March Point and Petit Jardin Formations) comprise muddy and sandy carbonates, deposited in tidal flats and sand shoals (Levesque, 1977; Figure 2). During Early Ordovician time, widespread subtidal conditions existed on the platform, resulting in abundant mudstone accumulation (James and Stevens, 1982).

The St. George Group is divided into four formations (Knight and James, personal communication, 1983), namely the Watts Bight Formation (80 m thick) which is overlain by the Boat Harbour Formation (120 m thick), the Catoche Formation (200 m thick), and the Aguathuna Formation (60 m thick) (Figure 2). The Boat Harbour and Aguathuna Formations are similar lithologically; both consist of cycles of intercalated subtidal limestone, mottled dolostone, and supratidal planar laminated, in places mudcracked, dolostone (Pratt, 1979). The intervening Catoche Formation consists of thick sections of dark gray, fossiliferous subtidal limestone. Mottled, peloidal mudstone and wackestone of the upper third of the Catoche Formation mark upward shoaling into an intertidal regime. This upper third of the Catoche Formation is complexly dolomitized, characterized by abrupt diagenetic fronts, breccias, and megacrystalline (1 mm) white dolomite which hosts the zinc ore.

The transition from the Aguathuna Formation to the Middle Ordovician Table Head Group is marked by one or more disconformities. Stouge (1982), using conodonts, recognized a biostratigraphic break and possible lacuna 10 m above the base of the Aguathuna Formation. Another discontinuity with 16 m of erosional relief occurs between the Aguathuna and Table Point Formations near Port au Port, Newfoundland (Figure 1). At Daniel's Harbour, strata above this particular horizon fill paleotopographic depressions generated by solution collapse, faulting, or both (Figures 3 and 4). These disconformities are equivalent to the Knox-Beekmantown unconformity of the central and southern Appalachians (Rodgers, 1971; Mussman, 1982).

During Middle Ordovician time (White Rock Stage), widespread subtidal conditions were re-established on the platform as recorded by the limestones of the Table Head Group (Klappa et al., 1980). Near the end of Table Head Group deposition, the platform rapidly subsided and ribbon limestones, shale, carbonate debris flows, and turbidites were deposited. These were covered by an easterly derived siliciclastic flysch and, finally, tectonically emplaced ophiolitic allochthons. Subsequently, the Grenville basement was uplifted and the cover rock was broken into a series of subparallel fault zones and monoclines.

From this regional overview, it is apparent that several environmental conditions may have influenced the formation of the breccias: (1) shoaling on the carbonate platform during St. George Group deposition; (2) overlying disconformity with a local erosion surface and collapsed paleotopography (the St. George - Table Head break); (3) subsequent tectonic downwarping of the platform prior to allochthon emplacement; and (4) faulting during uplift of the Grenville basement.

Stratigraphy and Geometry of the Ore and Host Rocks

In the vicinity of the mines at Daniel's Harbour, the sphalerite ore is stratigraphically and lithologically restricted to megacrystalline (1 mm crystal size) dolostones of the upper third of the Catoche Formation. This part of the Catoche Formation has been complexly dolomitized, and only 25% of it remains unaltered limestone. The major dolostone types include: (1) an assemblage of intercalated strata of megacrystalline (1 to 5 mm) white dolomite and fine crystalline (0.01 mm) gray dolomite and white dolomite veins, comprising 50% of the upper Catoche Formation; (2) 20% pervasive coarse crystalline (0.1 to 1 mm) vuggy gray dolomites; and (3) 5% gray fine

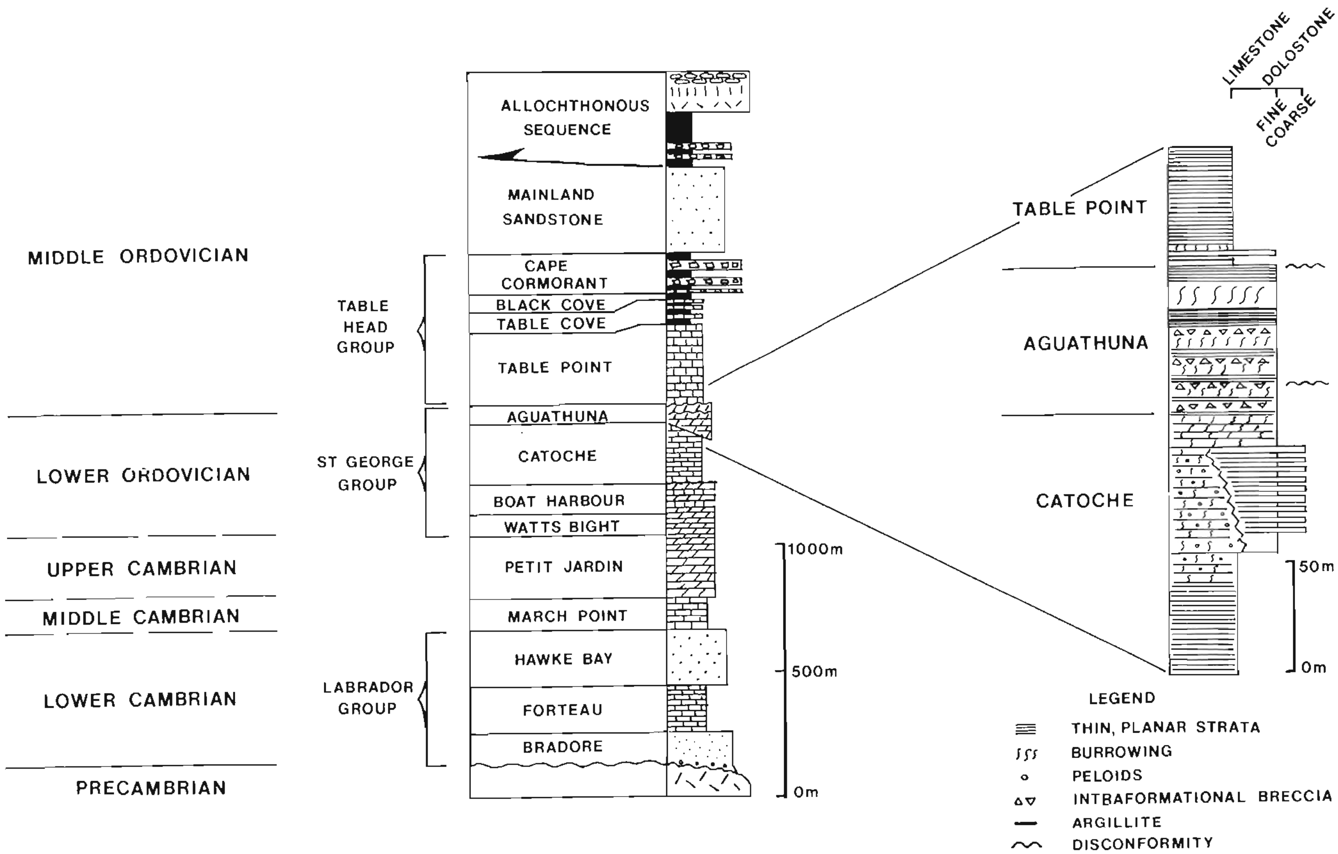


Figure 2: *Stratigraphy from Newfoundland Zinc Mines set in the stratigraphy of the Humber Zone Autochthon (adapted from James and Stevens, 1982).*

rock matrix breccias (matrix size = 0.01 mm, fragment size = 1 mm to 1 m). Fine rock matrix breccias are restricted to structural depressions in upper St. George Group strata (Figure 3). The other dolostones are developed outside the "breccia-depressions". The overlying upper 16 m of the Catoche Formation and the entire Aguathuna Formation are pervasively dolomitized and contain only minor white dolomite. These dolostones are mostly microcrystalline (0.01 mm) and commonly finely planar laminated (dololaminites). The variety of dolostones of the upper St. George Group is described by Collins and Smith (1975), Coron (1982), and Haywick and James *(this volume)*.

At least 11 ore bodies, averaging 8% zinc, have been defined to date within the white dolostone. Individual ore lenses are long, narrow, and sinuous, 5 to 15 m (rarely up to 30 m) thick, 7 to 70 m wide and 500 to 4000 m long. Their linearity is caused by ore-controlling vein systems which in part border structural depressions oriented 045° to 060° and 180° (Figure 3). Although the veins control the orientation of the ore, most of the sphalerite was deposited in white dolomite strata, peripheral to the veins.

Sphalerite stratigraphy and paragenesis have been used with some success at other Mississippi Valley type deposits (McLimans et al., 1980; Craig et al., 1983). At Daniel's Harbour, as many as four stages of sphalerite precipitation are recognized by color changes in mineralization lining previous cavities. Relative

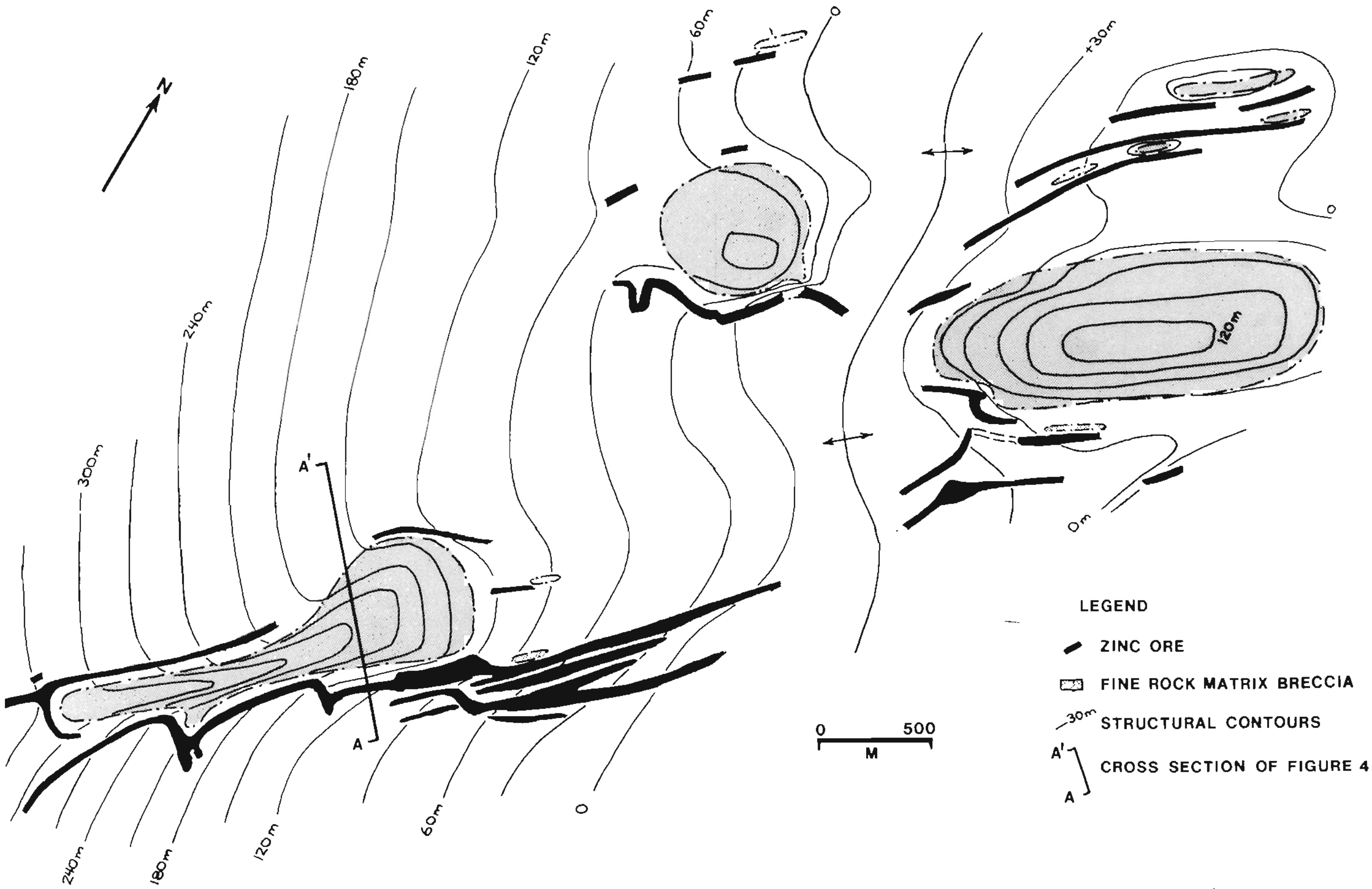


Figure 3: *Newfoundland Zinc Mines. A plan view of the upper Catoche Formation, showing the location of zinc orebodies relative to structural depressions and the distribution of fine rock matrix breccias. Structural contours record the depth of an upper Catoche stratum below a datum plane 100 m above sea level (contour interval = 30 m).*

ages of brecciation can be tested by the presence or absence of these sphalerite stages.

Classification of Breccia Types

Five breccia types are differentiated on the basis of macrotexture, petrography, and geometry (Table 1):

(1) intraformational breccias;

(2) fine rock matrix breccias subdivided into (2a) oligomictic and (2b) polymictic types; and

(3) white spar breccias subdivided into (3a) true spar breccias and (3b) pseudobreccias.

The stratigraphic, compositional and geometric relationships of those breccias are summarized in Table 1 and Figures 4 and 5.

(1) Intraformational Breccias

The intraformational breccias possess a fine rock matrix, but are distinguished by their stratigraphic characteristics. They are extensive horizons specifically

Table 1: *Summary of stratigraphic, compositional and geometrical relationships observed within five breccia rock types at Newfoundland Zinc Mines.*

Type of Breccia		Stratigraphic Position	Composition	Geometry
Intraformational		Aguathuna Formation	Local angular dolostone clasts, chert clasts, nodules, sandy mud matrix, clay residues, clast and matrix support	Laterally extensive, strata-bound
Fine Rock Matrix	Oligomictic	Upper Catoche Formation	Local clasts (1-3 cm diameter), subrounded clasts, sandy mud matrix, matrix support; recrystallized clasts and matrix	Laterally continuous for 30 to 3000 m; localized around structural depressions and fracture zones
	Polymictic	Aquathuna and Upper Catoche Formations	3 or 4 mixed lithologies of clasts (1 cm to 1 m diameter), gravelly-sandy mud matrix, matrix support, clasts fractured, not recrystallized	Vertically crosscuts pre-existing dolostone; limited lateral extent; common around breccia margins
White Spar Breccias	True Breccias	Upper Catoche Formation	Large angular clasts (up to 1 m diameter) includes pseudobreccia; megacrystalline white dolomite matrix	Veins and bodies crosscutting strata; vertical fracture system
	Pseudobreccias	Upper Catoche Formation	Megacrystalline white dolomite replaces 5% to 80% of mottled gray dolomite; partial cavity infilling; minor breccia	Selectively replaces horizontal strata over thousands of metres

related to primary lithofacies. Stouge's (1982) conodont data indicate that these breccias may overlie disconformities.

Lithology - Angular rotated clasts (1 to 5 cm in diameter) derived from local, overlying dololaminites are enveloped by a recrystallized sandy to gravelly mud matrix. Green and black clay residues form part of the matrix and are concentrated at the base of breccias. Mud-filled fractures and mosaics of slightly displaced fragments are present where breccias are poorly developed. Chert occurs as clasts within breccias and horizons of nodules in underlying strata.

Geometry - The breccias are tabular bodies, 30 to 50 cm thick, which can be correlated between drill holes for a distance of at least 10 km.

Stratigraphic Association - The breccias occur in specific lithofacies successions in the Aguathuna Formation. They abruptly overlie burrow-mottled subtidal dolostones and underlie planar laminated supratidal dolostones (Figure 5). Locally, both breccias and underlying dolostones are recrystallized. This sequence is repeated six times in the Aguathuna Formation.

Genesis - The intraformational breccias are interpreted as synsedimentary or early diagenetic in origin. They mark abrupt breaks between subtidal and supratidal environments, which could be interpreted as either disconformities (e.g. Fischer's (1964) loferites or postdepositional dissolution surfaces (e.g. Lucia (1972)).

(2) Fine Rock Matrix Breccias

In contrast to intraformational breccias, fine rock matrix breccias are found within and around the structural depressions and fracture zones. Within these bodies of breccia, two major types can be distinguished based on petrography and geometry: oligomictic and polymictic types.

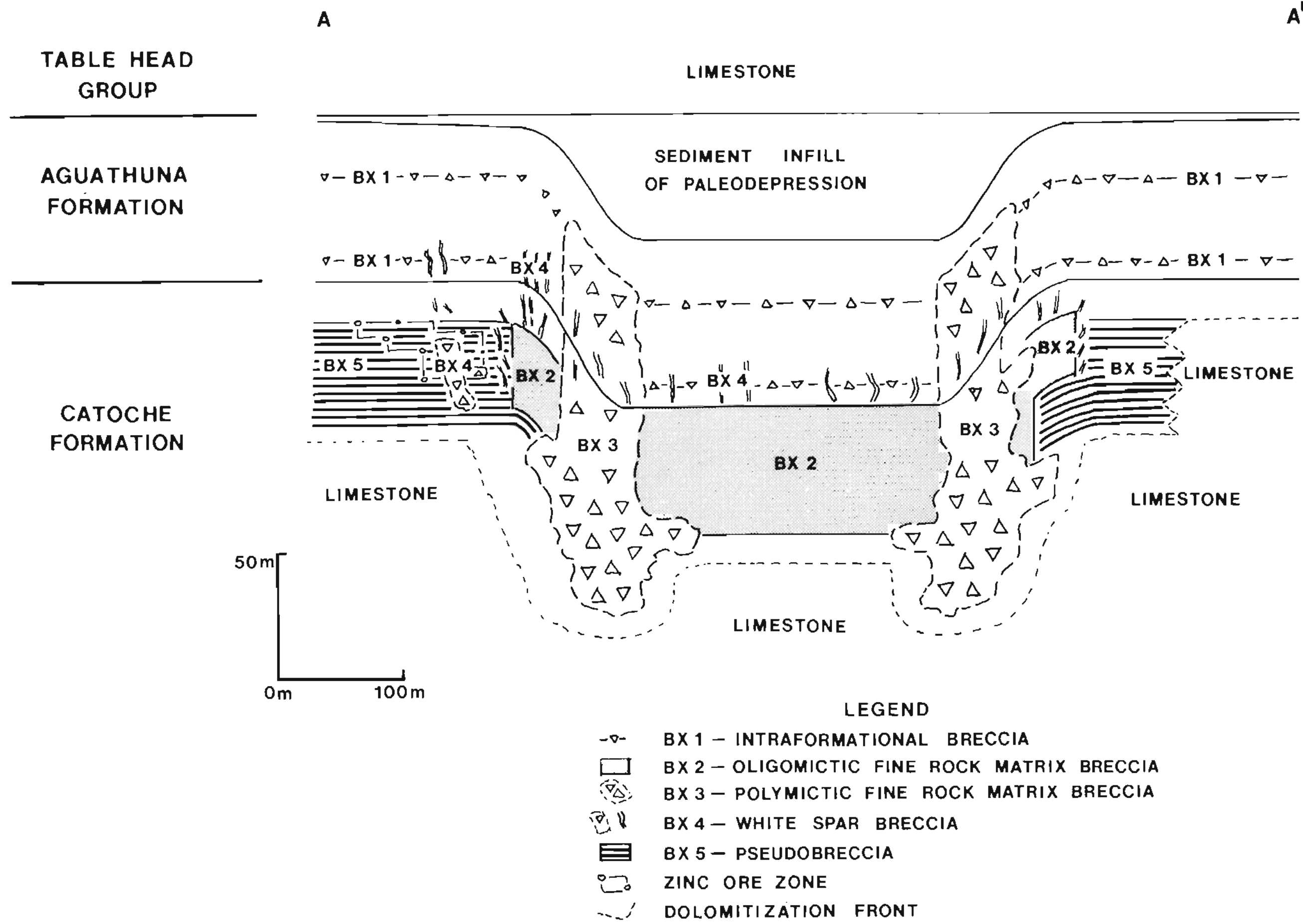


Figure 4: *Distribution of the five breccia types across an ore zone and a structural depression. Location of the cross-section is indicated on Figure 3.*

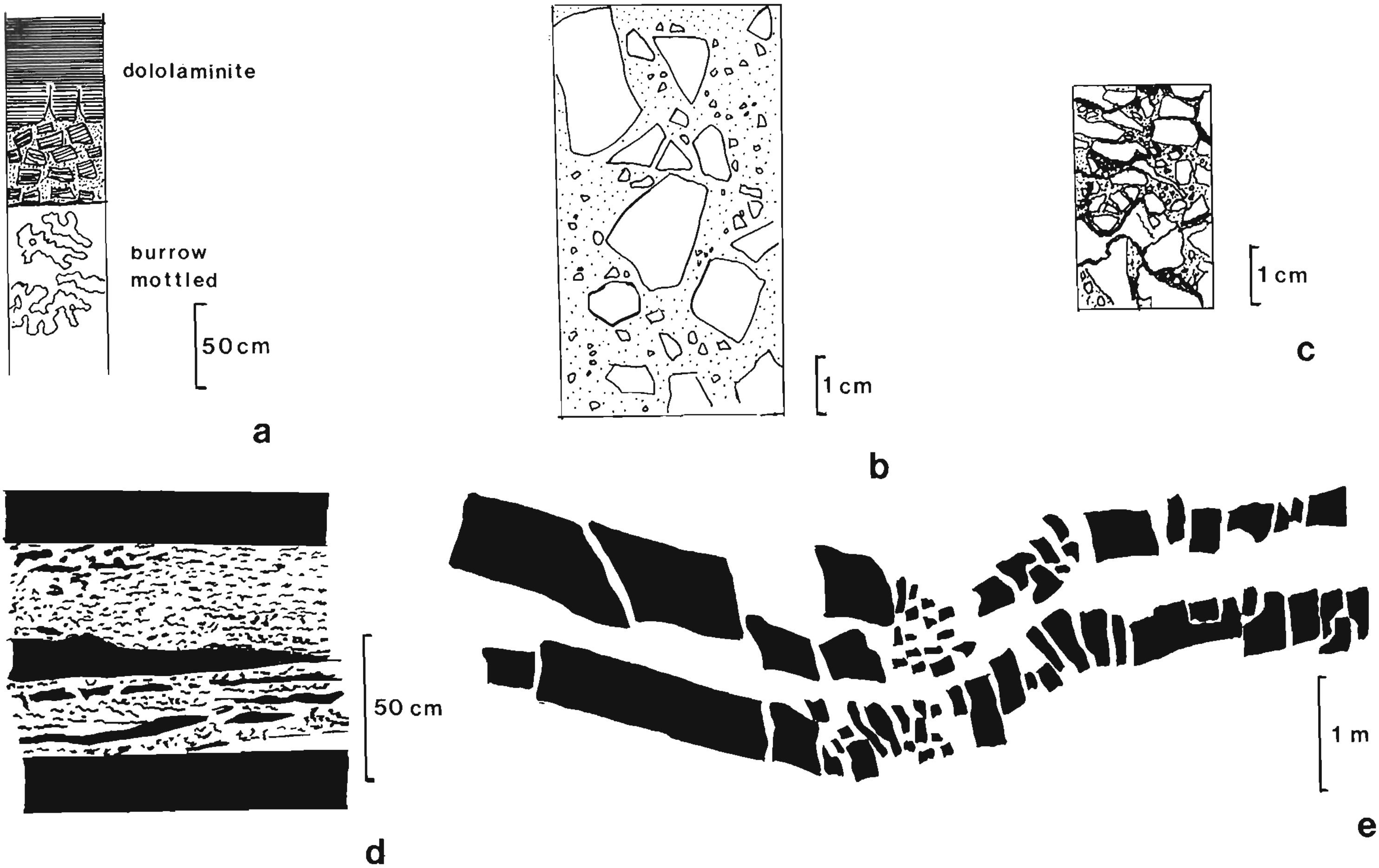
(2a) OLIGOMICTIC BRECCIAS

Lithology - Small fragments (0.1 to 1 cm diameter) consist of one lithology, mottled dolostone, derived from one stratigraphic level. These subrounded to subangular clasts are recrystallized to 0.1 mm dolomite. The rock is only partially matrix-supported, with clasts often bounded and separated by black residue-rich stylolites. The matrix is finely crystalline (0.01 mm), fairly homogeneous and rich in black residues (Figure 5). The residues were identified by Collins (1971) as iron oxides.

Geometry - These breccias are stratigraphically controlled and can be correlated within and slightly beyond the boundaries of the structural depressions, laterally continuous up to 200 by 1000 m (Figure 3). As well, some small, 10 m wide, oligomictic breccia bodies occur in association with fracture zones.

Stratigraphic Association - The oligomictic breccias are restricted to the upper Catoche Formation, constituting 60% to 90% of the section. Overlying strata are intact and characterized by common veins of gray and white dolostone.

Genesis - The upper Catoche Formation underwent local dissolution and dolomitization during the formation of the structural depressions, prior to the deposition of the Table Head Group and the later sphalerite emplacement. Dissolution resulted in the collapse of strata and the production of breccias, and, in part, the



a. *Intraformational breccias relative to dololaminite and burrow mottled lithofacies. Clay residues at the base of the breccia.*

b. *Polymictic fine matrix breccia, with fragments "floating" in matrix.*

c. *Oligomictic fine rock matrix breccia with fragments compacted and black residue in matrix and between clasts.*

d. *Pseudobreccia with horizontal fabric, between grey dolomite strata.*

e. *Grey dolomite strata broken by subsidence and faulting to form a true spar breccia.*

Figure 5. *Aspects of breccia macrotextures.*

formation of the major structural depressions; fractures which propagated through overlying strata were later filled with veins. The porous breccias provided permeability for dolomitizing fluids, which produced the pervasive recrystallization.

(2b) POLYMICTIC BRECCIAS

Lithology - Clasts of up to four lithologies are intermixed, the most distinctive of which are light gray laminated clasts characteristic of the Aguathuna Formation. The clasts range in size from 1 m to 1 cm. The angular, commonly fractured clasts float in 40% to 70% poorly sorted matrix comprising 1 to 5 mm clasts and 0.1 mm euhedral dolomite crystals enveloped in black residues (Figure 5).

Geometry - These breccias crosscut the stratigraphy. One unit was observed to be 10 m wide with vertical boundaries. Information from other areas indicates irregular widening at specific stratigraphic levels.

Stratigraphic Association - The breccias tend to be localized around the margins of the structural depressions and crosscut the stratigraphy of the Aguathuna Formation through the upper 60 m of the Catoche Formation. Clasts of the Aguathuna Formation have been displaced up to 60 m below their original stratigraphic position.

Genesis - The origin of the polymictic breccias is directly related to structural changes at the margins of depressions.

Dilation at the rims caused by collapse or downfaulting created enough space for rock debris to fall as much as 60 m. The openings may have also been enlarged by dissolution, forming significant cavities that were subsequently filled with breccia.

(3) White Spar Breccias

Megacrystalline white dolomite is extensive in the vicinity of the ore zones; however, it is not present in areas containing matrix breccias. The white dolomite is considered to be younger than the fine rock matrix breccia which it locally replaced. Much of the white dolomite was precipitated at the same time as the sphalerite.

In this classification, distinction is made between true spar breccias and pseudobreccias. A true spar breccia contains displaced and rotated gray dolomite fragments surrounded by a matrix of megacrystalline white dolomite. The gray dolomite patches of pseudobreccia often appear to be surrounded by megacrystalline white dolomite. The gray dolomite patches of pseudobreccia often appear to be surrounded by megacrystalline white dolomite; however, they are *in situ* and interconnected in three dimensions (Figure 5). The white dolomite of pseudobreccia is either open-space-fill or a recrystallization fabric. Since true spar breccias and pseudobreccias are overprinted in places, the distinction is not always clear.

(3a) TRUE SPAR BRECCIAS

Lithology - Angular fragments of gray dolomite and pseudobreccia, up to one metre in diameter, are supported by a matrix of megacrystalline white dolomite. These fragments have often only slightly rotated from their original position. A few spar breccias were originally fine rock breccia. In these cases, white spar has selectively replaced gray dolomite matrix.

Geometry - Three types of spar breccia are delineated: (1) veins in gray dolomite strata between pseudobreccia; (2) local breccias within pseudobrecica beds; and (3) linear bodies which crosscut the stratigraphy (10 to 30 m wide and 100 m or more long). Linear breccias are usually a collection of subvertical veins.

Stratigraphic Association - These breccias are restricted to the Upper Catoche Formation. Their occurrence is controlled by vein density, faulting and subsidence of strata.

Genesis - Spar breccias formed where strata were ruptured by faulting and/or dissolution. Large fragments of these strata were slightly displaced and rotated. Some of these breccias were cogenetic with pseudobreccias; however, the larger linear bodies are late structures, associated with vertical movements, and formed after most pseudobreccia development. Only late stage sphalerite occurs in these dolomites.

(3b) PSEUDOBRECCIA

Lithology - Megacrystalline white dolomite constitutes 5% to 80% of strata 0.3 to 1 m thick. The remainder of the rock consists of dispersed irregular patches of medium crystalline gray dolomite with an internal relict mottled fabric. Intercrystal and vug porosity is abundant. White and gray dolomite alternate in a horizontal, variably developed, 'banded' fabric (Figure 5). Breccia fragments of gray dolomite occur locally in veins and cavity fills.

Geometry - Pseudobreccia strata and intercalated gray dolostones are selectively developed according to textural variation in the original limestones. As a result, it is possible to correlate specific strata over distances greater than 15 km. The highest percentages of white dolomite are concentrated around vein systems, but pseudobreccia development in strata extends laterally over thousands of metres.

Stratigraphic Association - Pseudobreccia development is limited to strata 16 to 50 m below the top of the Catoche Formation. The position coincides with the upper limit of limestones and the occurrence of cyclic, mottled, peloidal mudstones and wackestones. In this interval, pseudobreccia is excluded from areas of the older fine rock matrix breccia.

Genesis - Pseudobreccia formed by diffusion of dolomitizing fluids into peloidal limestone strata to a depth of 50 m below the top of the Catoche Formation. Linear vein systems were the loci of fluid movement, the area of best spar development, and ore conduits. White dolomite crystallized by selective replacement around early dolomites (Haywick and James, *this volume)* and filling of vugs and cavities. Sphalerite was deposited prior to and during white dolomite formation.

Conclusions

Five breccia types occur in association with sphalerite deposits at Daniel's Harbour, Newfoundland. Differentiation of breccia styles is essential to an understanding of the permeability, porosity evolution, and subsequent sphalerite deposition. Subaerial exposure of the carbonate platform is suggested by intraformational breccias. Fine rock matrix breccias formed by dissolution and collapse beneath this exposed platform. Early structural dilation along the margins of large depressions (200 m by 1000 m) resulted in the formation of polymictic breccias. Subsequent deformation produced open space fracture systems which became filled by sphalerite and megacrystalline white dolomite. Peloidal limestone strata were altered to pseudobreccia outward from vein systems. Most sphalerite was precipitated in pseudobreccia strata adjacent to veins. Linear spar breccias formed as a result of vertical tectonic movements during the latest stages of mineralization.

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