GEOLOGY OF THE DRIFTPILE STRATIFORM, SEDIMENT-HOSTED Ba-Zn-Pb DEPOSIT, NORTHERN BRITISH COLUMBIA (94K/4)

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INTRODUCTION

One of the world's largest concentrations of sediment-hosted stratiform zinc-lead-barite deposits is located in the Gataga area of northern British Columbia (Figure 1). The largest and most developed of these is the Cirque/South Cirque deposit, with estimated geological reserves of 38.5 million tonnes averaging 8.0% Zn, 2.2% Pb and 47.2 g/tonne Ag at Cirque and 15.5 million tonnes of 6.9% zinc, 1.4% lead and 32 g/tonne Ag at South Cirque (MacIntyre, 1992). The Driftpile deposit, located 80 kilometres north of Cirque, has been explored and drilled extensively in 1978-1982 by Archer, Cathro and Associates and from 1993 to the present by Teck Exploration Ltd. In spite of this considerable development, most information about the Driftpile deposit resides in private company reports. Notable exceptions are a Ph.D. thesis by Martin Insley (Insley, 1990) that includes a 1:5000 geologic map and cross-sections of the property and diamond drill hole logs; and a suite of conodont identifications based on Insley's collections, which appear in S.E.B. Irwin's M.Sc. thesis (Irwin, 1990).

This paper summarizes preliminary results of a one-month study on the detailed stratigraphy and mineralization of the Driftpile deposit, conducted in August 1994. Core from 25 holes drilled in 1993 and 1994 was logged and sampled for studies of conodont biostratigraphy and taxonomy by S.E.B Irwin and M.J. Orchard of the Geological Survey of Canada, and the area around Driftpile Creek was mapped at 1:2000 scale. This deposit study is a cooperative effort between the B.C. Geological Survey Branch and the Geological Survey of Canada (see companion paper, Paradis *et al.*, 1995). It forms part of a multidisciplinary program in the Gataga area which also includes regional mapping (Ferri *et al.*, 1995, this volume) and geochemical studies (Lett and Jackaman, 1995, this volume).

EXPLORATION HISTORY

The Driftpile Creek property was first staked in 1974 by Canex Placer Ltd. in joint venture with a syndicate, as a result of follow-up of anomalies from a stream sediment geochemical survey conducted by Geophoto Consultants Ltd in 1970. Encouraging additional results from sampling,, as well as the discovery of massive sulphide float boulders in Driftpile Creek in 1973 led to staking of 153 two-post claims in 1974, and a program of geological mapping, EM and hand trenching in 1974-75. The Gataga Joint Venture was formed in 1977 by Aquitaine Company of Canada, Chevron Canada Ltd., Getty Mining Pacific Ltd. and Welcome North Mines Ltd. Managed by Archer, Cathro and Associates, its aim was to investigate the potential of the Kechika Trough in terms of sedimentary exhalative deposits like those of the Selwyn Basin. The Gataga Joint Venture optioned the Driftpile property in 1978 and from then until 1982 conducted a major exploration program including 7560 metres of drilling in 54 diamond-drill holes, geological mapping, grid soil geochemistry, EM surveys, backhoe trenching and the construction of an airstrip. This program outlined an extensive series of northwest striking barite and sulphide-carbonate units, outcropping over an area 3 kilometres northwest-southeast by 1.5 kilometres northeast-southwest (Carne and Cathro, 1982a). Particularly favourable zones such as the Main, Camp, East, North Trench and Canyon zones, shown on Figure 2, were drill tested.

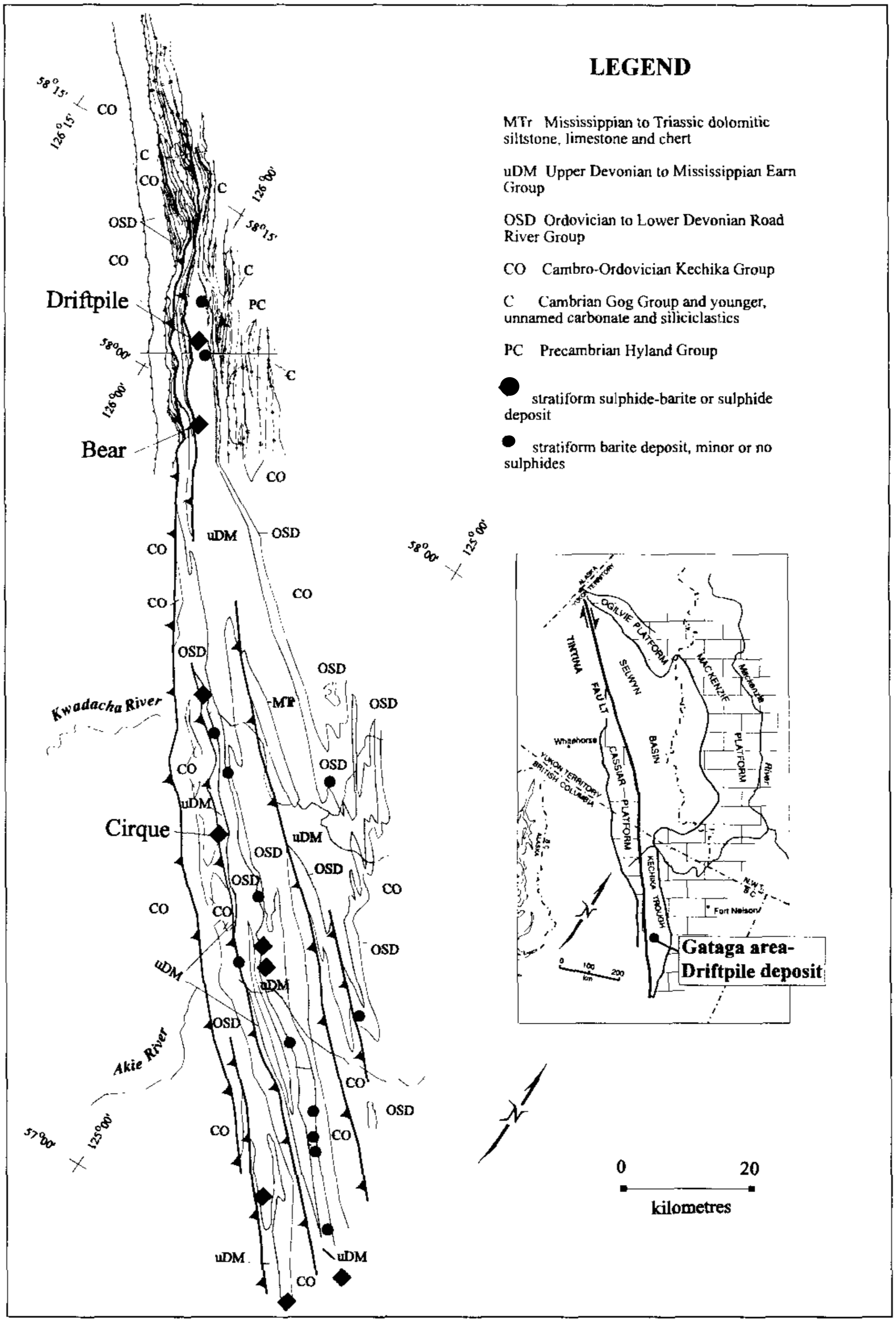

Figure 1. Regional geology of the central and southern Kechika Trough. Geology by MacIntyre (1992) and McClay *et al.*, (1989) for the area around the Driftpile deposit. Earn Group exposures shaded grey.

Following a ten-year hiatus in activity, Teck Exploration purchased the property in 1992. Teck drilled 4600 metres in thirteen holes in 1993, testing the Main zone. As a result of this work, a geological resource in the lower mineralized unit of the Main zone was estimated to be 2.44 million tonnes averaging 11.9% Zn, 3.1% Pb with a cutoff grade of 8% Zn (Farmer *et al.*, 1994). The 1994 program included drilling of 4400 metres in 26 holes on the East, Camp, Ridge and Canyon zones.

REGIONAL GEOLOGY

The Gataga area lies within the Muskwa Range of the northern Rocky Mountains, directly east of the Northern Rocky Mountain Trench - Tintina strike-slip fault system (Gabrielse, 1985). It includes part of the Kechika Trough or Kechika Basin, a southern continuation of the Selwyn Basin in Yukon. This feature has been variously interpreted as a two-sided trough (McClay *et al.*, 1989; MacIntyre, 1992) or west-facing open continental slope (Gabrielse, 1985; personal communication, 1994) during early Paleozoic time. Upper Cambrian through Lower Devonian strata are thin and of deep water facies, in contrast to the carbonate-dominated section exposed to the east. They are included within the Cambro-Ordovician Kechika Group and Ordovician to Lower Devonian Road River Group (Figure 1). The regional geology is more thoroughly described in the companion paper by Ferri *et al.* (this volume).

Although stratiform, sediment-hosted deposits of Middle Ordovician and Early Silurian age are present within the Kechika Trough, the major pulse of exhalative activity was in the Late Devonian. The Earn Group, a basinal siliciclastic package of Middle Devonian to early Mississippian age, hosts regionally extensive stratiform barite and many stratiform sulphide (-barite; -carbonate) occurrences, including Driftpile and the Cirque deposit (Figure 1). Correlative strata are exposed throughout the Selwyn Basin, where they host significant sedex deposits such as Tom and Jason, and on the Cassiar Terrane, where similar deposits are small and rare. The Earn Group represents a dramatic change in basin history. In it, easterly to southeasterly prograding coarse clastic wedges interfinger with black shales, siliceous shales, cherts and mudstones. The latter facies has been informally termed the Gunsteel formation from its silvery-blue appearance in outcrop. It hosts the stratiform barite and sulphide (-barite; -carbonate), which in the Kechika Trough are of Famennian age (Irwin, 1990). In the vicinity of the Cirque deposit, clastic rocks overlie the Gunsteel formation and its contained exhalite unit (Pigage, 1981); but at the Bear claims, 10 kilometres south of Driftpile, coarse clastic rocks occur at the base of the Earn Group in a panel west of the Mount Waldemar fault (McClay *et al.*, 1989). The relative stratigraphic position of exhalites and siliciclastics is an important issue, because it shows temporal relationships between regional tectonic activity and exhalative pulses.

Jura-Cretaceous crustal shortening of the ancestral North America continental margin deformed the Paleozoic to Triassic strata of the Kechika Trough into a complex, mainly northeast-verging fold and thrust belt. McClay *et al.* (1989) recognize five major thrust panels, defined by rocks of strongly contrasting stratigraphic levels and, in some cases, contrasting facies as well. The thrust faults that bound the major panels may be reactivated Paleozoic growth faults. Within each major panel, the strata are folded and stacked in duplexes. The Devonian exhalite occurrences are found in the central thrust panel. A stack of upper Road River and Earn Group horses is exposed within this panel, bounded by décollements at the base of the upper Road River Group and within the Earn Group. The Driftpile deposit is truncated to the west by the major thrust fault that bounds this panel, informally termed the Mount Waldemar fault. Graptolitic black shale of the lower Road River Group forms the immediate hangingwall of the fault. More regionally, the Mount Waldemar fault underlies a duplex of Road River and Earn Group strata including very coarse Earn clastics not seen in its footwall. It has been interpreted as a reactivated basin-bounding fault; and its position as the southwestern boundary of the Driftpile deposit suggests that this early structure may have channelled fluids that gave rise to the exhalative mineralization (McClay *et al.*, 1989; R. Carne, personal communication 1994).

GEOLOGY OF THE DRIFTPILE DEPOSIT

STRATIGRAPHIC SETTING OF THE DRIFTPILE DEPOSIT

The Driftpile deposit consists of several separate stratiform sulphide-carbonate and barite bodies, each folded and bounded by thrust faults (Figures 2, 3). They are hosted by the lower Earn Group, a sequence of black to dark grey shale, mudstone, argillite, siliceous mudstone and shale, and lesser chert. Conodont collections from in and stratigraphically near mineralization are all of roughly middle Famennian age; most precise dating indicates conodont fauna of the lower rhomboidea, lower marginifera and upper marginifera zones (Irwin, 1990). Archer, Cathro geologists recognized three distinct sulphide and/or barite units, designated in ascending order UH, NH and TH (Carne and Cathro, 1982a, b). Insley (1990) recognized one sulphide-carbonate unit M1, which passes laterally into a barite facies, and four overlying barite units, M2 through M4. The monotony of the hangingwall and footwall rocks, and the intense folding and faulting, make the distinction, correlation and extension of sulphide and barite units a matter of guesswork. The presently existing conodont data have not resolved the problem.

Diamond-drill hole 93-55 (Figure 4) provides one of the more complete stratigraphic sections in the Main zone area a few hundred metres west of the barite kill zone on surface (Figure 4). The lowest unit, from 310 metres depth to the bottom of the hole at 367 metres, is a black, sooty, somewhat siliceous shale. It contains sparse, wispy beds of quartz siltstone, and a few trains of oval pyrite-carbonate nodules. The base of the sulphide-carbonate unit is sharp, but apparently conformable. Its bottom few centimetres are interbedded with black siliceous shale with discontinuous radiolarian chert beds. Radiolarian chert is a characteristic component of the footwall of the sulphide-carbonate unit throughout the deposit, and is commonly interbedded with its base.

The sulphide-carbonate unit itself is dominated by laminated pyrite. Individual laminae range from 0.1 millimetre to nearly a centimetre in thickness, and may coalesce to form almost massive pyrite. They wrap around coarse-grained grey calcite concretions, which constitute up to 30% of the rock. Upwards, the sulphide zone is increasingly diluted with thin beds of mudstone and black shale. This hangingwall contact may be transitional over tens of metres. In the transition zone, the thin, black shale interbeds contain abundant sulphide laminae, but are separated by increasingly abundant grey, graded mudstone beds. These mudstones are interpreted as distal turbidites. Higher in the hole, the intervening black shales lose their pyrite content. In terms of event stratigraphy, it seems that an initial pulse of sulphide-rich exhalite was first diluted by very fine grained clastic influx before it began to wane.

The hangingwall unit is a turbidite sequence composed of interbedded grey mudstone and black shale. The average thickness of individual mudstone beds increases stratigraphically upwards. Immediately above the sulphide-carbonate unit they may be very thin, giving the rock a well-laminated appearance. Hundreds of metres above the unit they range up to metres thick. In thin section the mudstones are well graded and contain silt-sized quartz, chert and a few muscovite clasts.

A number of textural features are characteristic of the hangingwall unit. Coarse grained calcite concretions

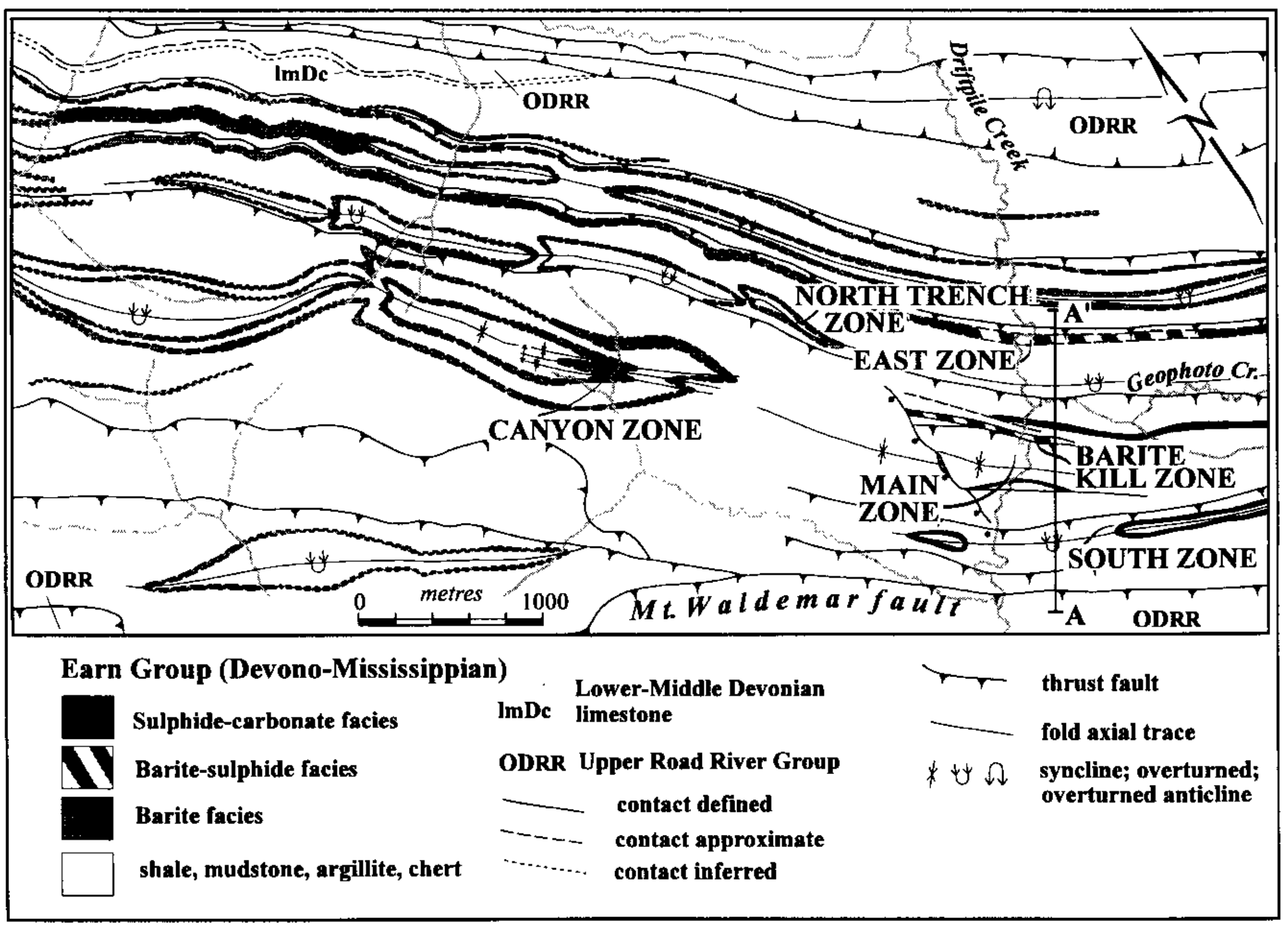

Figure 2. Detailed geology of the Driftpile Creek area. After Insley (1990), with modifications in the southeast corner from drilling and mapping by Teck Exploration in 1993 and 1994. The exploration camp is located at the prominent U-bend in Driftpile Creek, just north of the Mt. Waldemar fault. Cross-section A-A' is Figure 3.

range in abundance from 5 to 10% immediately above the sulphide-carbonate unit, to one every few metres higher in the hole. These concretions are much larger that those in the sulphide unit, from a few up to 30 centimetres across. They are consist of one, or of several overlapping spheres. In outcrop, amalgamations of concretions also form apparently stratiform bodies. Strings of pyrite-carbonate and barite nodules, each a few millimetres in diameter, parallel bedding. They tend to higher concentratations in the upper parts of the mudstone beds, although they also occur in the black shale interbeds. They increase somewhat in abundance upwards. Where calcite concretions occur with the barite or pyrite-carbonate beads, they surround them. Wispy beds of tan siltstone are rare but persistent. They are made up of many fine laminae. Their edges are irregular, concavo-convex in outline. Interestingly, these fine, distal clastic units show no correlation with the graded mudstones that make up most of this unit. They occur in equal abundance in the other units, such as the footwall black shale or even the sulphide units themselves.

Most Main zone drill holes were collared in the hangingwall unit. However, in hole 93-55, the uppermost thick grey mudstone of the hangingwall unit is overlain along a sharp depositional contact by sooty black carbonaceous, siliceous shale with abundant radiolarian chert interbeds. This unit bears a close resemblance to the footwall of the sulphide-carbonate unit. It is overlain conformably by black mudstone, finely striped with thin pyrite laminae. Teck geologists refer to this texture as the cryptic pyrite-laminated mudstone. It is interpreted as a distal equivalent of a sulphide unit. In hole 93-55 its upper contact is a faulted section many metres across. This fault is thought to have reverse motion; above the hangingwall unit of interbedded grey mudstone and black shale is repeated.

THE SULPHIDE-CARBONATE AND BARITE-SULPHIDE UNITS

Detailed mapping and logging of 1993 and 1994 core allowed the construction of an east-west cross section at 13N, about 200 metres south of Driftpile Creek (Figure 3). The stratigraphic sequence in hole 93-55 is also intersected in the lower part of hole 93-58, shown on Figure 3. This sequence provides clear evidence for two separate pyrite-rich units, the lower Main zone and an upper, much weaker unit that consists only of fine pyrite laminations in mudstone. On Figure 3, the Main zone projects into the near surface between the barite kill zone and Geophoto Creek where it is intersected by hole 78-06. The upper unit projects to surface at the barite kill zone. By this construction, massive to laminated barite is characteristic of the upper unit in addition to laminated pyrite.

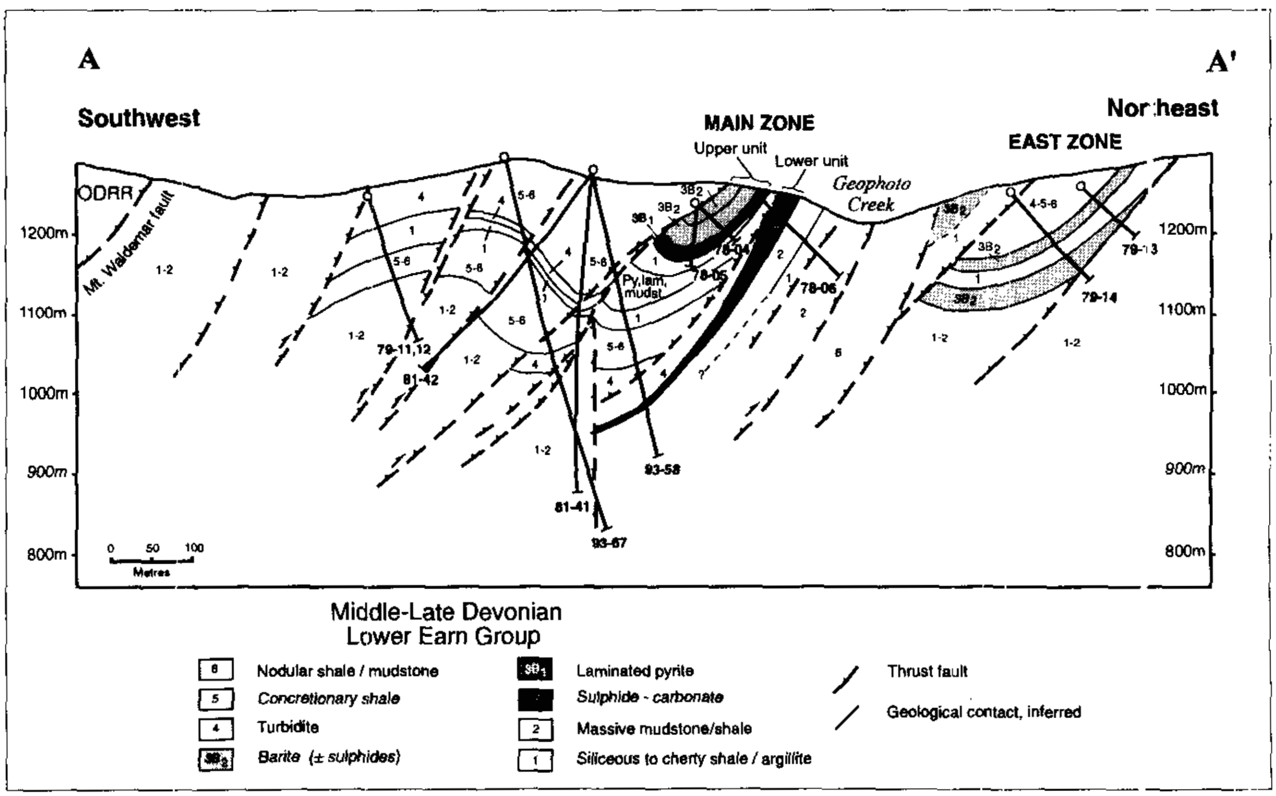

Figure 3. Detailed cross-section of the Main and East zones along grid 13+00 North, showing 1993 and earlier drill holes. Some outcrop data has been projected from the banks of Driftpile Creek (approximately line 15+00 North).

Of all the economically interesting units on the property, the lower, sulphide-carbonate unit in the Main zone is best understood at present. Drilling by Teck Exploration in 1993 delineated it for 800 metres along strike and 300 metres down dip across the upright, faulted syncline shown in Figure 3. This section is near the southern limit of the lower unit. Although it is intersected in hole 93-58, there is no equivalent in either hole 81-41 or 93-67. Teck geologists postulate an east-trending growth fault that limits the sulphide unit to the south. This inferred fault approximately parallels the axes of maximum thickness and of grade for the unit (Farmer *et al.*, 1994). The estimated true thickness of the sulphide-carbonate unit varies from 20 to 70 metres. It is variably diluted by mudstone turbidites and black shale. In some areas, massive sulphide with visible sphalerite and galena occurs near its base. Most of this unit, however, consists of laminated spheroidal and framboidal pyrite with subordinate amounts of sphalerite and galena. Sphalerite occurs as intergrowths and interstitial grains within the pyrite framboids.

As shown on Figure 3, the East zone is in a separate thrust panel from the Main zone, and therefore their relative stratigraphic positions are not known. The East zone sulphide-carbonate-barite unit is well exposed on the south bank of Driftpile Creek. It is roughly 50 metres thick, with interbedded pyrite-carbonate and black siliceous shale with radiolarian chert near its base, a central pyrite-barite(-carbonate) section in which pyrite and barite occur as sets of coarse laminations with lesser argillite interbeds, and an upper section in which blebby, bedded barite becomes more prominent

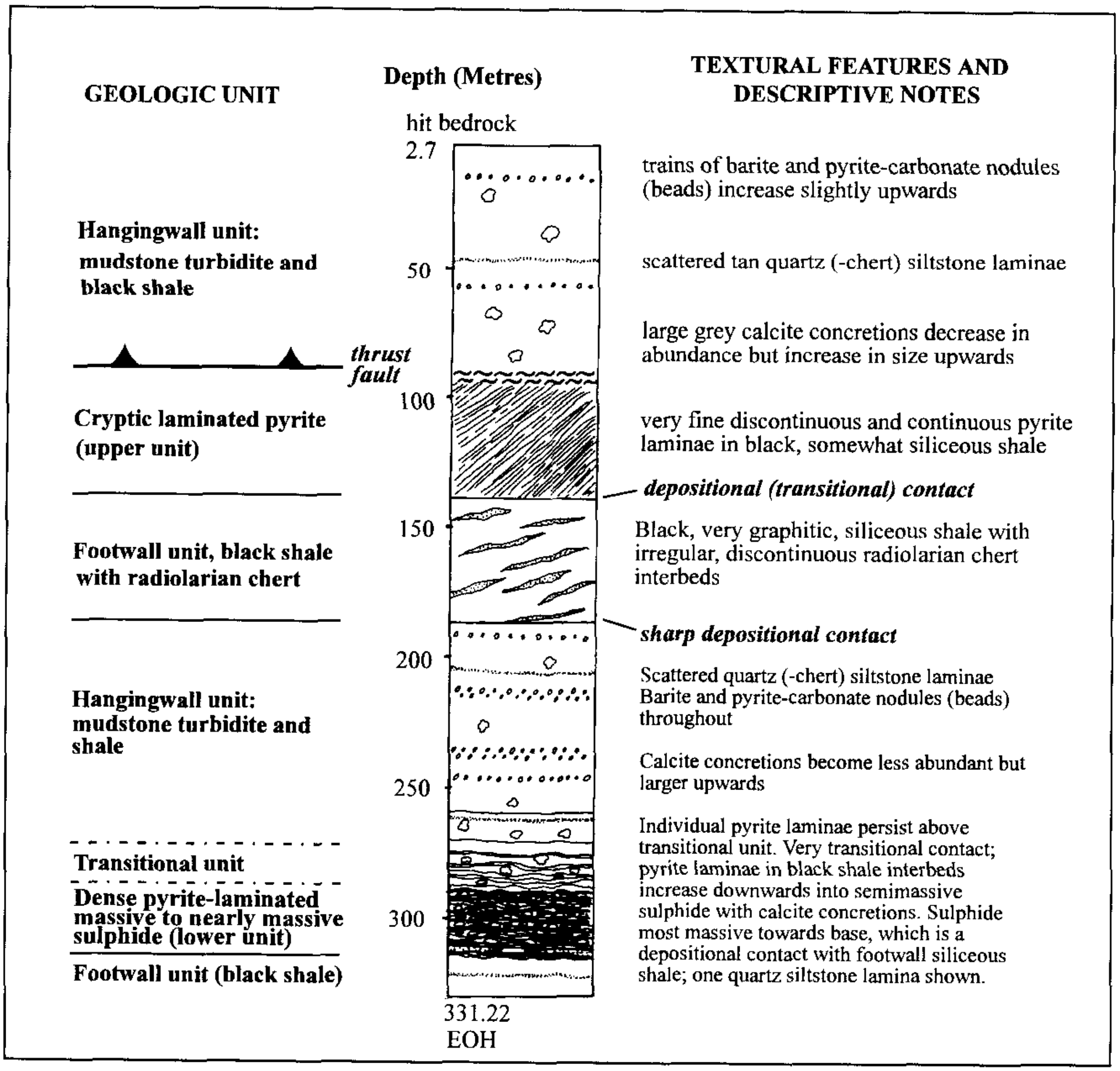

Figure 4. Stratigraphic log of Teck diamond-drill hole 93-55, from the Main zone.

upwards. Although in most respects this unit resembles the lower unit of the Main zone, the abundance of barite towards its top suggests a correlation with the barite kill (upper) zone. It is hoped that conodont data will settle this issue.

STRUCTURE

The lower Earn Group in the vicinity of the Driftpile deposit is broken into northwest-striking thrust panels parallel to the Mount Waldemar fault (Figures 2, 3). The thrust faults dip moderately southwest. Within the panels, strata are folded into open folds with moderately to steeply southwest-dipping axial planes and gently northwest-plunging (10-20°) fold axes. The cores of larger folds are occupied by broad zones of intense, disharmonic chevron folding - "M" and "W" folds. This feature renders vergence data from the sparse outcrops in the Driftpile Creek valley of equivocal value in large-scale structural interpretations. Most of the major folds are upright, except for the south zone near the Mount Waldemar fault, where a tight syncline is overturned to the northeast. In the Main zone, a southwest-dipping reverse fault offsets the western limb of a syncline (Figure 3). In core, this fault and others with demonstrable offsets are expressed as crush zones several metres wide. Such obvious correlation between offset and mechanical expression casts some doubt on the existence of cryptic, unrecognizable bedding-parallel thrust faults in core, although they cannot be ruled out.

Although several cleavages are observed in outcrop and in core, one is clearly dominant. It strikes northwesterly and is steeply dipping to vertical. It is axial planar to the major folds. Teck geologists, with caution, used the general consistency of this cleavage as an aid in establishing core orientation. This technique proved useful, except in very steeply inclined holes and those collared near major thrust faults. In the argillites, cleavage-bedding angles are typically moderate to large, in keeping with the open nature of the folds. As the sulphide-carbonate zones are approached, however, bedding is transposed into cleavage and mesoscopic folds are abundant. It is likely that the more ductile sulphides folded disharmonically and were thickened in fold hinges to a greater extent than their host argillites.

DISCUSSION

Core logging, detailed mapping and construction of an east-west cross-section along Driftpile Creek have established a preliminary stratigraphic and structural framework for understanding the stratiform mineralization The stratigraphy of the Earn Group at the Driftpile deposit shows at least two cycles of exhalative activity. Each is preceded by extremely euxinic, starved sedimentation as evidenced by the footwall siliceous shale and radiolarian chert. Each is succeeded directly by an influx of distal mud turbidites. This event stratigraphy may represent an interplay of tectonics and mineralization, in which discrete episodes of faulting triggered, first the release of metal-bearing brines and then, shortly afterwards, sediment transport down newly steepened slopes, perhaps accompanied by convective overturn of the water column. Ideally, conodont data may resolve the relative passage of time represented in the footwall, mineralized units and hangingwall units.

Diamond drilling in 1993 and 1994 has established two pyrite units in the Main zone: but correlation of these zones with others such as the East and Canyon zones depends on precise faunal ages. Only when the relative stratigraphic position of these is well established can property-scale facies variation within zones be addressed, and any reliable basin reconstruction be attempted.

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REFERENCES

Carne, R.C and Cathro, R.J. (1982a): Summary Report, 1978-1982; Exploration by the Gataga Joint Venture on the Driftpile Creek Property; unpublished internal report, Archer, Cathro and Associates (1981) Ltd., 67 pages

Carne, R.C and Cathro, R.J. (1982b): Sedimentary Exhalative (Sedex) Zinc-Silver-Lead Deposits, Northern Canadian Cordillera; *Canadian Institute of Mining and Metallurgy*, Bulletin, Volume 75, pages 66-78.

Farmer, R., Oliver, J. and Evans, G. (1994): Diamond Drilling on the Driftpile Creek Property (P,D, Goof and Pook Claims), Liard Mining Division NTS 94K/4W, 58°04' North, 125°55' West; *B.C. Ministry of Energy, Mines and Petroleum Resources*, Assessment Report.

Ferri, F., Nelson, J. and Rees, C. (1995); Geology and Mineralization of the Gataga River Area, Northern Rocky Mountains (94L/7, 8, 9 and 10); *in* Grant, B. and Newell, J., editors, *B.C. Ministry of Energy, Mines and Petroleum, Resources*, Geological Fieldwork 1994, Paper 1995-1 (this volume)./

Gabrielse, H. (1985): Major Dextral Transcurrent Displacements along the Northern Rocky Mountain Trench and Related Lineaments in North-central British Columbia; *Geological Society of America*, Bulletin, Volume 96, pages 1-24.

Insley, M.W. (1990): Sedimentology and Geochemistry of the Driftpile Ba-Fe-Zn-Pb Mineralization, Northeastern British Columbia; unpublished Ph.D. thesis, *Royal*

Holloway and Bedford New College, University of London, 377 pages.

Irwin, S.E.B. (1990): Late Devonian Conodont Biostratigraphy of the Earn Group with Age Constraints for Stratifrom Mineral Deposits, Selwyn and Kechika Basins, Northern British Columbia; unpublished M.Sc. Thesis, *The University of British Columbia*, 311 pages.

Lett, R.E. and Jackaman, W. (1995): Geochemical Orientation Survey in the Driftpile Creek Area, Northeastern British Columbia (94K,L); *in* Grant, B. and Newell, J., editors, *B.C. Ministry of Energy, Mines and Petroleum, Resources*, Geological Fieldwork 1994, Paper 1995-1 (this volume).

McClay, K.R., Insley, M.W. and Anderton, R. (1989): Inversion of the Kechika Trough, Northeastern British Columbia, Canada; *in* Inversion and Tectonics, Cooper, M.A. and Williams, G.D., Editors, *Geological Society of London,* Special Publication 44, pages 235-257.

MacIntyre, D.G. (1992): Geological Setting and Genesis of Sedimentary Exhalative Barite and Barite-Sulphide Deposits, Gataga District, Northeastern British Columbia; *Canadian Institute of Mining, Metallurgy, and Petroleum*, Exploration and Mining Geology, Volume 1, pages 1-20.

Paradis, S., Nelson, J.L. and Farmer, R. (1995): Stratigraphy and Structure of nthe Driftpile stratifrom Ba-Zn-Pb Deposit, Gataga Area, Northeastern British Columbia in Current Research, 1995-A, *Geological Survey of Canada* .

Pigage, L.C. (1981): Geology of the Cirque Barite-Zinc-Lead-Silver Deposits, Northeastern British Columbia; *in* Mineral Deposits of the Northern Cordillera, Morin, J., Editor; *Canadian Institute of Mining and Metallurgy,* Special Volume 37, pages 71-86.