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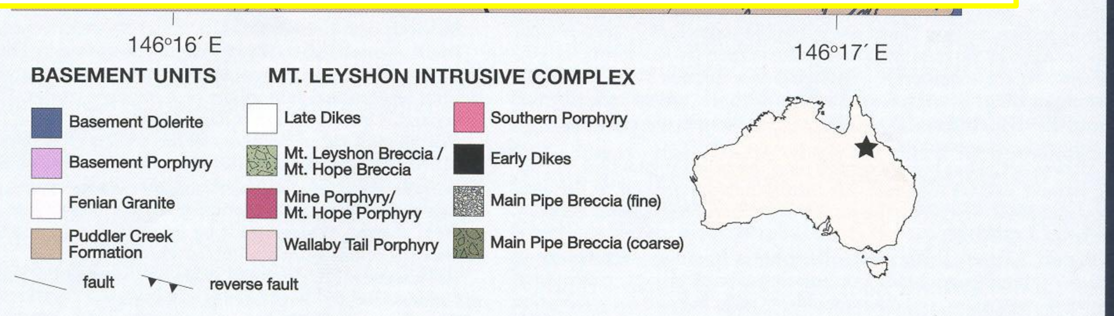
Here is an extract (first four pages) of a recent article that mentions the Dufferin deposit and compares it with world class deposit including the Bendigo, Australia.

Voici un extrait (premières quatre pages) d'un article récemment publié qui mentionne le gîte Dufferin et le compare avec des gisements de classe mondiale dont celui de Bendigo en Australie.

Alain Hupé Eng.
President
Ressources Appalaches



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A Carbonaceous Sedimentary Source-Rock Model for Carlin-Type and Orogenic Gold Deposits

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Abstract

This paper presents evidence and arguments that carbonaceous sedimentary rocks were a source for Au and As in sediment-hosted orogenic and Carlin-type gold deposits and develops a corresponding genetic model. In this two-stage basin-scale model, gold and arsenic are introduced early into black shale and turbidite basins during sedimentation and diagenesis (stage 1) and concentrated to ore grades by later hydrothermal, structural, or magmatic processes (stage 2). In reduced continental margin basin settings, organic matter, sedimented under anoxic to euxinic conditions, immobilizes and concentrates gold, arsenic, and a range of trace elements (particularly V, Ni, Se, Ag, Zn, Mo, Cu, U) present in marine bottom waters, into fine-grained black mudstone and siltstone of slope and basin facies. During early diagenesis, gold and certain other trace elements (Ni, Se, Te, Ag, Mo, Cu, ±PGE) are preferentially partitioned into arsenian pyrite that grows in the muds. These processes produce regionally extensive black shale and turbidite sequences enriched in syngenetic gold and arsenic, commonly from 5 to 100 ppb Au and 10 to 200 ppm As. Rare organic- and sulfide-rich metalliferous black shales may contain up to 1 to 2 ppm Au and over 1,000 ppm As, present as refractory gold in arsenian pyrite and nanoparticles of free gold.

During late diagenesis and early metamorphism (stage 2) the diagenetic arsenian pyrite is recrystallized to form coarser grained pyrite generations, and the organic matter is cooked to bitumen. Under higher grade metamorphism (lower greenschist facies and above) arsenian pyrite in carbonaceous shales is converted to pyrrhotite. These processes release gold, arsenic, sulfur and other elements (Sb, Te, Cu, Zn, Mo, Bi, Tl, and Pb) from the source rocks to become concentrated by hydrothermal processes, locally to produce gold ores, in structural sites such as fold hinge zones, shear or breccia zones within or above the black shale sequence.

LA-ICP-MS analyses of diagenetic pyrite in carbonaceous sediments, both associated and not associated with gold deposits, suggests that invisible gold contents of greater than 250 ppb in diagenetic pyrite, are indicative of carbonaceous shale source rocks with the potential to produce economic gold deposits. Application of this sedimentary source-rock model enables a systematic exploration approach for sediment-hosted gold deposits, based on the distribution, composition and structure of carbonaceous shale sequences and their contained diagenetic pyrite.

Introduction

THIS INVESTIGATION sought to determine whether, or not, carbonaceous sedimentary rocks could have been an important source for gold in orogenic and Carlin-type gold deposits. Development of the resulting model has been stimulated by an industry collaborative AMIRA International research project (Large et al., 2007, 2009; Chang et al., 2008; Meffre et al., 2008; Scott et al., 2008), combined with previous ideas on gold ore genesis presented by Boyle (1979), Buryak (1982), Kribek (1991), Titley (1991), Hutchinson (1993), Cooke et al. (2000), Hofstra and Cline (2000), Emsbo (2000), Reich et al. (2005), and Wood and Large (2007). Our research has been focused on Sukhoi Log (Siberia), Bendigo (Victoria), and the northern Carlin Trend (Nevada) but also includes data from Spanish Mountain (British Columbia), Macraes (South Island New Zealand), and Kumtor (Kyrgyzstan).

Although there is some consensus on aspects of the models for orogenic and Carlin-type gold deposits, there remains a number of unresolved questions (Groves et al., 2003; Cline et al., 2005). The model presented here challenges three current views related to orogenic gold deposits: (1) gold-rich fluids are derived from deep metamorphic processes or from crustal granites—we contend the gold is sourced in the sedimentary basin; (2) organic-rich sediments are traps for gold—we contend that organic-rich sediments are excellent source rocks for gold and a variety of other elements (As, Zn, V, Mo, Ag, Ni, Se, Te); and (3) gold is introduced late, i.e., syn- or posttectonic—we contend that gold is introduced early (syndiagenetic) and remobilized and concentrated locally on a scale of meters to kilometers during syntectonic and/or synmagmatic fluid flow.

The gold ores under consideration have been variously categorized as orogenic, turbidite-hosted, and Carlin-type gold deposits. They are strata bound and discordant to bedding, comprised of disseminated pyrite (±arsenopyrite and pyrrhotite) concentrated in black shale, siltstone, carbonate, and sandstone sequences (Table 1; Figs. 1, 2). Some of the world's largest gold districts and/or deposits are of this type (e.g., Muruntau, Ashanti, northern Carlin Trend, Kumtor, Homestake, Sukhoi Log; Table 1). Quartz veining may or may not be present (Fig. 2). Gold may be refractory (dissolved within arsenian-pyrite or arsenopyrite) or, in the case of many deposits, occurs as free gold or gold tellurides within metamorphic and/or hydrothermal pyrite, arsenopyrite, or associated quartz veins. The key criteria for considering this diverse group of deposits together is that they are hosted by sedimentary rocks and, in particular, carbonaceous mudstones or shales make up a significant component of the sedimentary

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TABLE 1. Some Major Sediment-Hosted Gold-Arsenic Deposits and Districts (modified after Goldfarb et al., 2005)

Deposit	Location	Au (t)	Au grade (g/t)	Age of host rocks	Sedimentary lithologic units
Alaska-Juneau	U.S. Cordilera	281	1.4	Late Jurassic-Early Cretaceous	Metasediments
Macreas Flat	New Zealand	251	1.2	Jurassic	Carbonaceous schists
Spanish Mountain	Western Canada	54	0.8	Triassic	Carbonaceous mustone, graywacke
Natalka	Russian Far East	716	4.2	Permian	Carbonaceous mustone, sandstone
Nezhdaninskoye	Russia	311	5.4	Early Permian	Carbonaceous siltstone, sandstone
Bakyrichik	Tien Shan Asia	361	6.8	Carboniferous	Carbonaceous metasediments
Carlin Trend	Nevada	3000	0.9 to 19	Siluro-Devonian	Calcareous carbonaceous mustone, limestone
Zarmitan	Tien Shan Asia	470	9.5	Silurian	Metasediments
Muruntau	Tien Shan Asia	5290	3.5-4.0	Ordovician-Silurian	Carbonaceous mustone, carbonate, sandstone
Amantaitau	Tien Shan Asia	288	3.7	Ordovician-Silurian	Carbonaceous metasediments
Bendigo	SE Australia	533	12.9	Lower Ordovician	Sandstone, carbonaceous mudstone
Getchell district	Nevada	800	3	Cambro-Ordovician	Calcareous carbonaceous mustone, limestone
Sukhoi Log	Edge Siberian craton	1920	2.8	Neoproterozoic	Carbonaceous mudstone, siltstone
Kumtor	Tien Shan Asia	284	4.4	Neoproterozoic	Mudstone, siltstone, sandstone
Telfer	Patterson, WA	1564	1.5	Neoproterozoic	Sandstone, mudstone
Olimpiada	Edge Siberian craton	700	10.9	Neoproterozoic	Schists, carbonaceous slates
Brasilia	Brazil	313	0.4	Neoproterozoic	Carbonaceous phyllite
Ashanti	West AfriCa	2070	4.7	Paleoproterozoic	Metasediments
Homestake	Trans-Hudson USA	1237	8.3	Paleoproterozoic	BIF, metasediments
Granites-Tanami	Central Australia	369	4.6	Paleoproterozoic	Metasediments, BIF

succession (Figs. 1, 2). For the orogenic deposits of this group, metamorphism and deformation have been critical processes in their genesis. In contrast, although deformation has been important in the genesis of Carlin-type deposits, the ores have formed in rocks of low metamorphic grade. Our view is that carbonaceous sediment-hosted gold deposits can form in a diverse range of environments from very low grade diagenetic to metamorphic (archizone) environments to moderate (green schist) metamorphic environments. Deposits in higher grade rocks (amphibolite and granulite facies) have

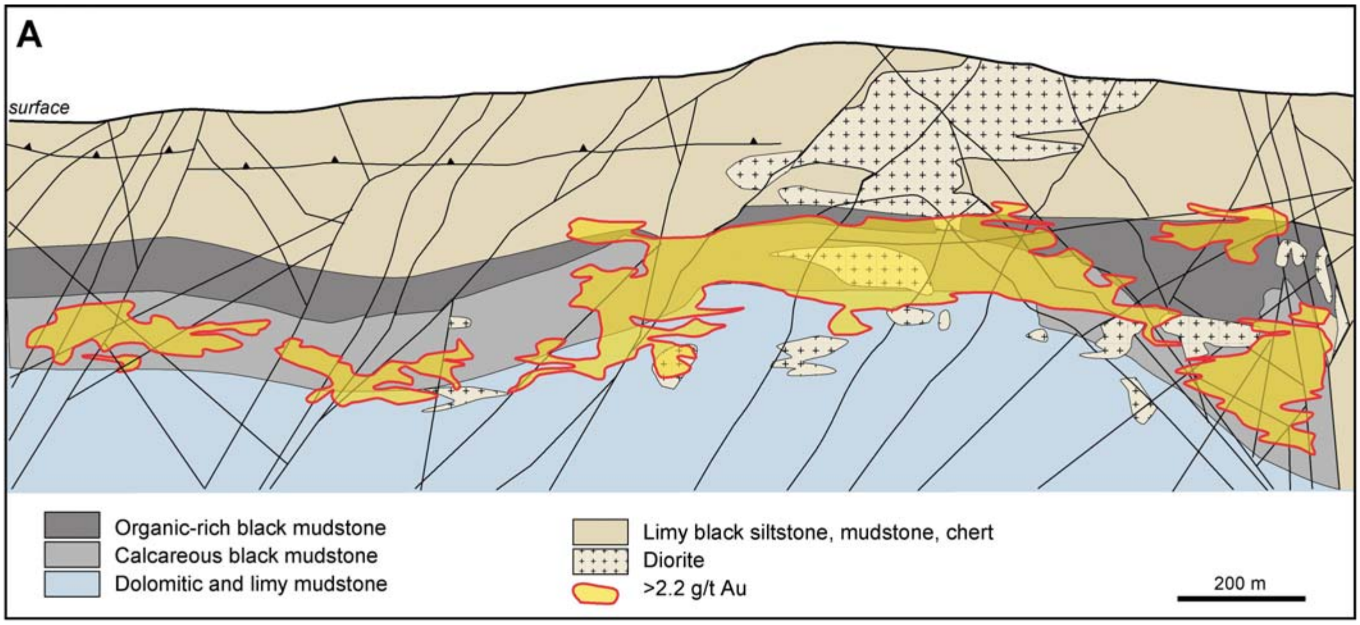

FIG. 1. Typical geologic cross sections showing relationship of carbonaceous sediments to orebodies in selected gold deposits. A. Betze-Post deposit, northern Carlin Trend (Bettles, 2002). Pyritic gold ores in yellow are strata bound and structurally controlled in the Popovich Formation. B. Sukhoi Log, Lena gold district (Wood and Popov, 2006). Pyritic gold ore is concentrated in an overturned anticline in carbonaceous shales and siltstones. C. Bendigo, central Victoria (Willman, 2007). D. Dufferin deposit, Meguma district (Ryan and Smith, 1998). Gold ores occur in quartz-rich saddle reefs and associated crosscutting quartz veins.

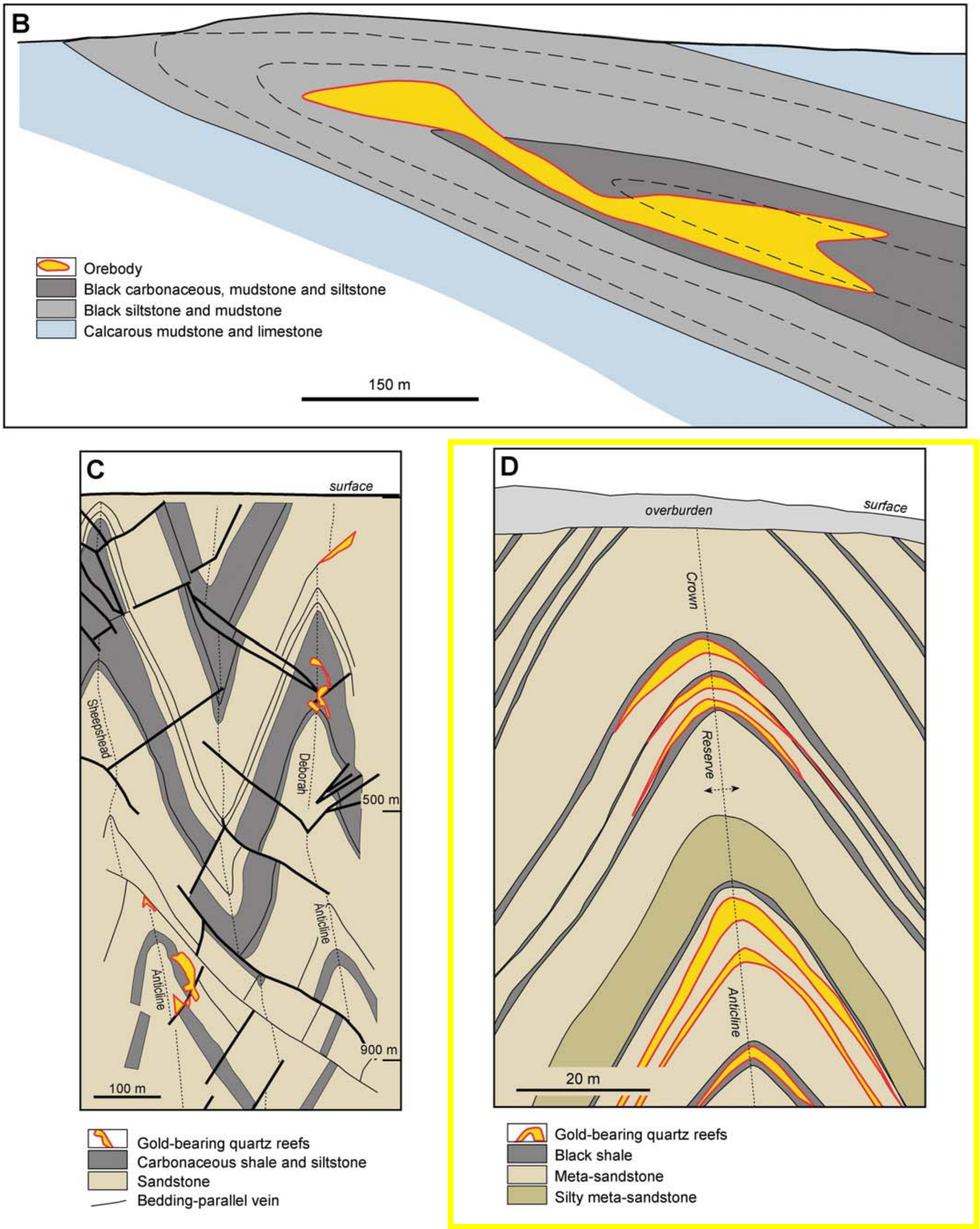

FIG. 1. *(Cont.)*

Dufferin deposit