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METALLIFEROUS BLACK SHALES AND RELATED ORE DEPOSITS—
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Geochemistry of the Ordovician High-Calcium Black Shales Hosting Major Gold Deposits of the Getchell Trend in Nevada

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Deep-water marine black shales (generally metamorphosed to greenschist facies) host significant gold deposits worldwide, among them Bendigo in Australia, Muruntau and Sukhoi Log in the U.S.S.R., and Sucha Rudna in Czechoslovakia. In the Nevada gold province, auriferous Paleozoic black shales are part of a carbonate turbidite assemblage consisting of silty carbonaceous limestone and dolomite. Unfortunately, the black shales have not been identified as a separate unit within this assemblage. We believe that several gold deposits in the Osgood Mountains and other areas are associated with black shales. In particular, Ordovician black shales of the Comus Formation and carbonaceous phyllite of the Cambrian Preble Formation are hosts for the Getchell Trend gold deposits, namely Rabbit Creek, Getchell, and Pinson (fig. 1). Another example of a mineralized black shale is the Pilot Shale of Mississippian and Devonian age, which hosts the Alligator Ridge gold deposit (Ilchik and Brimhall, 1986). On the other hand, the black shales of the Devonian Woodruff Formation in north-central Nevada are not known to host gold deposits. The geochemical and mineralogical properties of black shales that make them favorable hosts for gold mineralization are still poorly understood.

Our presentation concerns the black shales and dolomite mudstones of the Comus Formation. In the area of the Rabbit Creek gold deposit (Bloomstein and others, in press), the shales are 150–250 m thick. Based upon rhythmic bedding, graded beds, and characteristic conodont fauna, they are interpreted to be quiescent deep-water shales deposited in an anoxic environment. The shales are directly overlain by sparsely vesicular basalt flows believed to have formed at seawater depths between 500 and 1,800 m.

The unoxidized shales and mudstones consist of about 20 percent illite, 20 percent carbonate minerals (as aggregates and intraclasts of calcite and rhombohedral grains of dolomite), 40–45 percent detrital quartz, and 12–15 percent syngenetic pyrite as amorphous grains, framboids, and cubes. The organic carbon content of the shales of the Comus is generally 1–1.5 percent but may be as high as 5 percent. Organic matter is type I or II kerogen, marine algal in origin, as evidenced by large amounts of tricyclic terpane biomarkers and by high proportions of C27 and C28 sterane (Philp, 1985). Most of the organic carbon is overmature, having the rank of meta-anthracite; extractable bitumen in amounts of 30–80 ppm is also present. Gas chromatography results show that the bitumen consists of short-chain and long-chain n-alkanes. The presence of such immature material requires that bitumen migrated into the shales after the kerogen had thermally matured. All organic matter was introduced before the gold mineralization took place.

The shales of the Comus (table 1) are calcareous (11.35 weight percent CaO) and locally dolomitic (3.71 weight percent MgO). True limestones are not present. The TiO_2/Al_2O_3 ratio (0.087) may indicate a slight mafic volcanic input into the clastic material (Spears and Kanaris-Sotirou, 1976).

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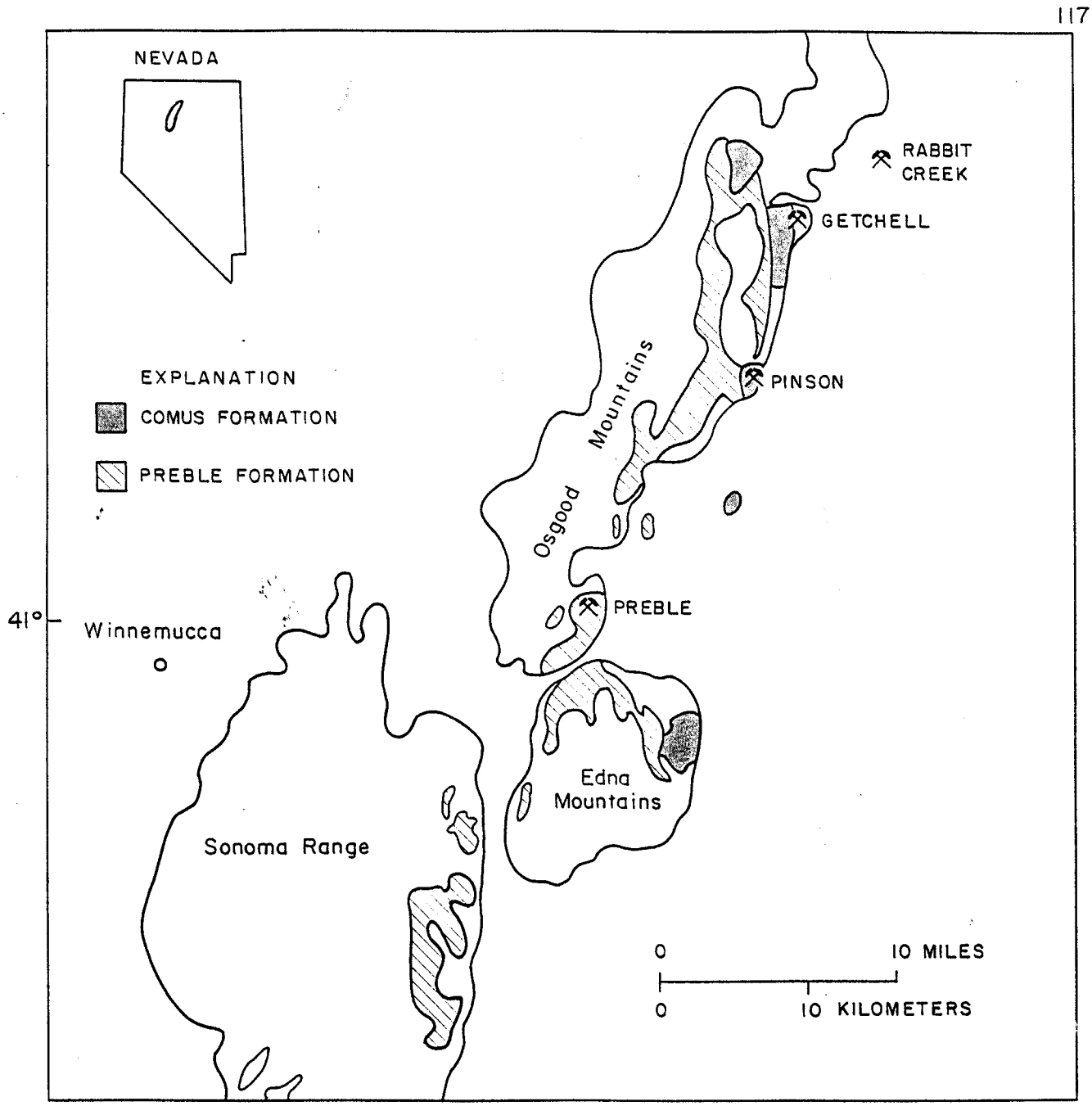

Figure 1. Location map of Comus and Preble Formation and associated gold mines in north-central Nevada.

Unmineralized samples of shales of the Comus were carefully selected to characterize the background geochemistry, but, because they are in close proximity to gold deposits, they may reflect a district-scale halo of mineralization. The shales of the Comus are enriched in As, Sb, Hg, and Ag (table 2), having abundances at least twice those of USGS Standard SDO-1.

Hydrothermal alteration of the Comus black shales at Rabbit Creek consists of decalcification and later silicification and dolomitization. These processes are illustrated on addition/depletion diagrams (figs. 2 and 3). Gold mineralization is associated with significant enrichment of As, Sb, and Hg and minor enrichment of Ba, Cu, Zn, and V (fig. 3).

The Pilot Shale has about the same amount and type of organic carbon (1–3 weight percent, marine) as the shales of the Comus, but the shales of the Woodruff have significantly more organic carbon (15 weight percent) that has a continental source (Dean and others, 1987). The shales of the Pilot and Woodruff are as calcareous and as

Table 1. Average chemical composition of unoxidized, unmineralized black shales of north-central Nevada
[In weight percent]

Unit	Associated gold deposit	SiO_2	Al_2O_3	CaO	MgO	FeO	Na_2O	K_2O	TiO_2	Ti/Al	Number of analyses
Comus Formation	Rabbit Creek	52.26	9.11	11.35	3.71	4.82	0.30	1.83	0.79	0.087	110
Pilot Shale	Alligator Ridge	53.50	4.32	5.67	3.82	2.35	0.17	1.58	0.24	0.056	3
Woodruff Formation	None	N/A*	6.55	13.02	7.00	1.77	0.17	2.07	0.26	0.040	4

*Not analyzed.

Table 2. Average trace element content of unoxidized, unmineralized black shales of north-central Nevada
[In parts per million. N/A indicates not analyzed]

Formation	Ba	Sr	As	Sb	Hg	Cu	Pb	Zn	Mo	V	Ni	Co	Ag	Th	U	Number of analyses
Comus Formation	47	128	231	9	2,774	25	7	48	2	14	13	8	0.36	3	6	28
Pilot Shale	330	328	330	9	453	30	12	149	5	67	74	13	0.27	6	2	3
Woodruff Formation	833	290	80	45	N/A	141	12	1,337	84	3,148	285	4	2.25	5	N/A	4
USGS Standard SDO–1	397	75	69	4	2	60	28	64	134	160	100	47	0.13	10	49	1–26*
Metalliferous Black Shale**	1,000	1,500	137	9	4	120	56	128	134	320	199	47	0.26	21	49	

*Number of analyses varies depending on the element.
**Huyck (1990, written commun.).

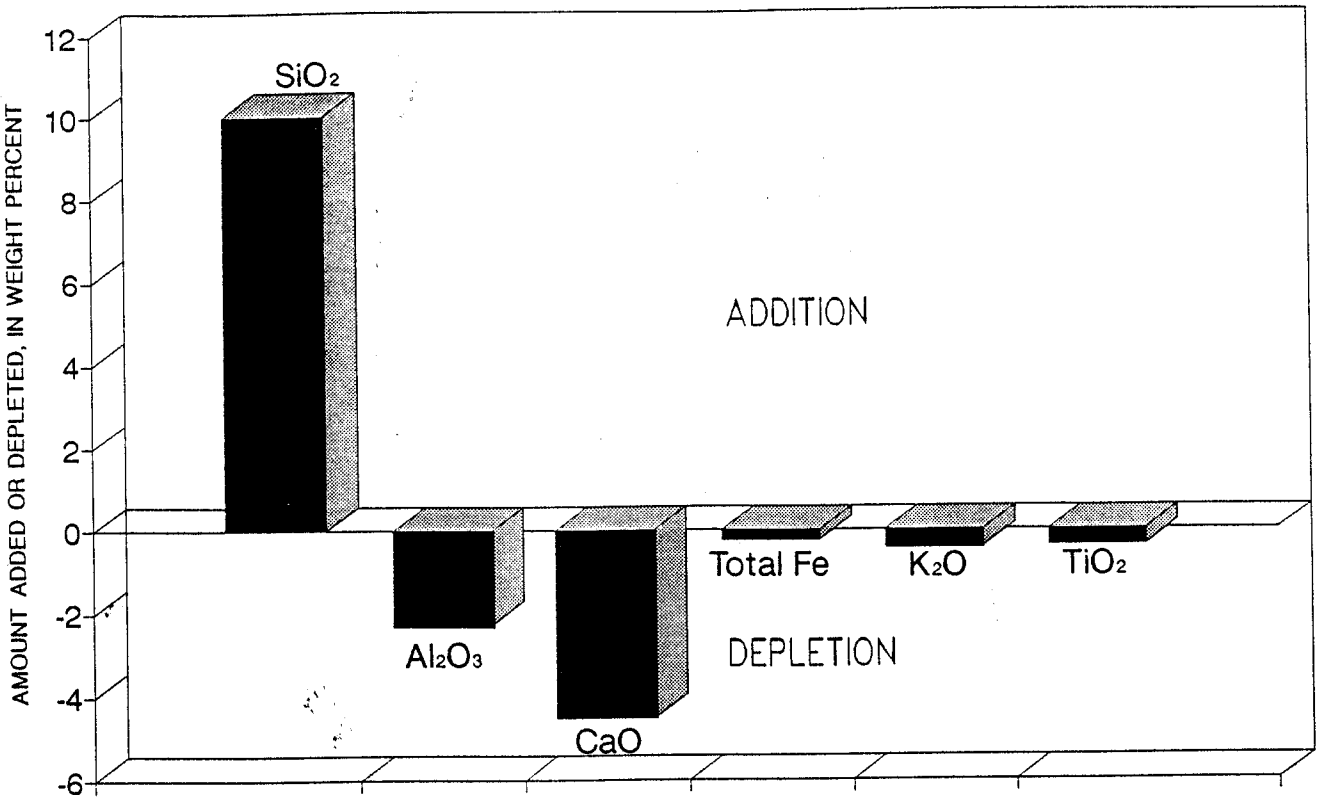

Figure 2. Geochemical addition and depletion associated with gold mineralization in the Comus Formation.

dolomitic as the shale of the Comus (table 1). Relative to the Comus, the source rocks for shales of the Pilot and Woodruff are apparently nonvolcanic and have lower TiO_2/Al_2O_3 ratios (0.056 and 0.040, respectively). Similar to the Comus, the Pilot Shale is enriched in As, Sb, Hg, Ag, Sr, and Zn relative to standard SDO–1. In contrast, the shales of the Woodruff are highly organic-rich black shales that have high contents of such trace elements as V, Ni, Zn, Cu, Ag, Sr, and Ba (table 2). Their composition is similar to that suggested as the standard for defining "metalliferous black shales" (H.L.O. Huyck, 1990, written commun.).

Geochemical features make Paleozoic black shales such as the Comus and Pilot favorable host rocks for Oligocene-Miocene gold mineralization: (1) relatively significant amounts of CaO (5–13 weight percent) and MgO (3–7 weight percent) allow decalcification and result in increased permeability; (2) relatively low organic carbon content (1–5 percent) promotes permeability; organic carbon content of more than 10 percent probably inhibits permeability; and (3) strong thermal maturation of organic carbon may provide high sorption capacity for precipitating gold from hydrothermal solution.

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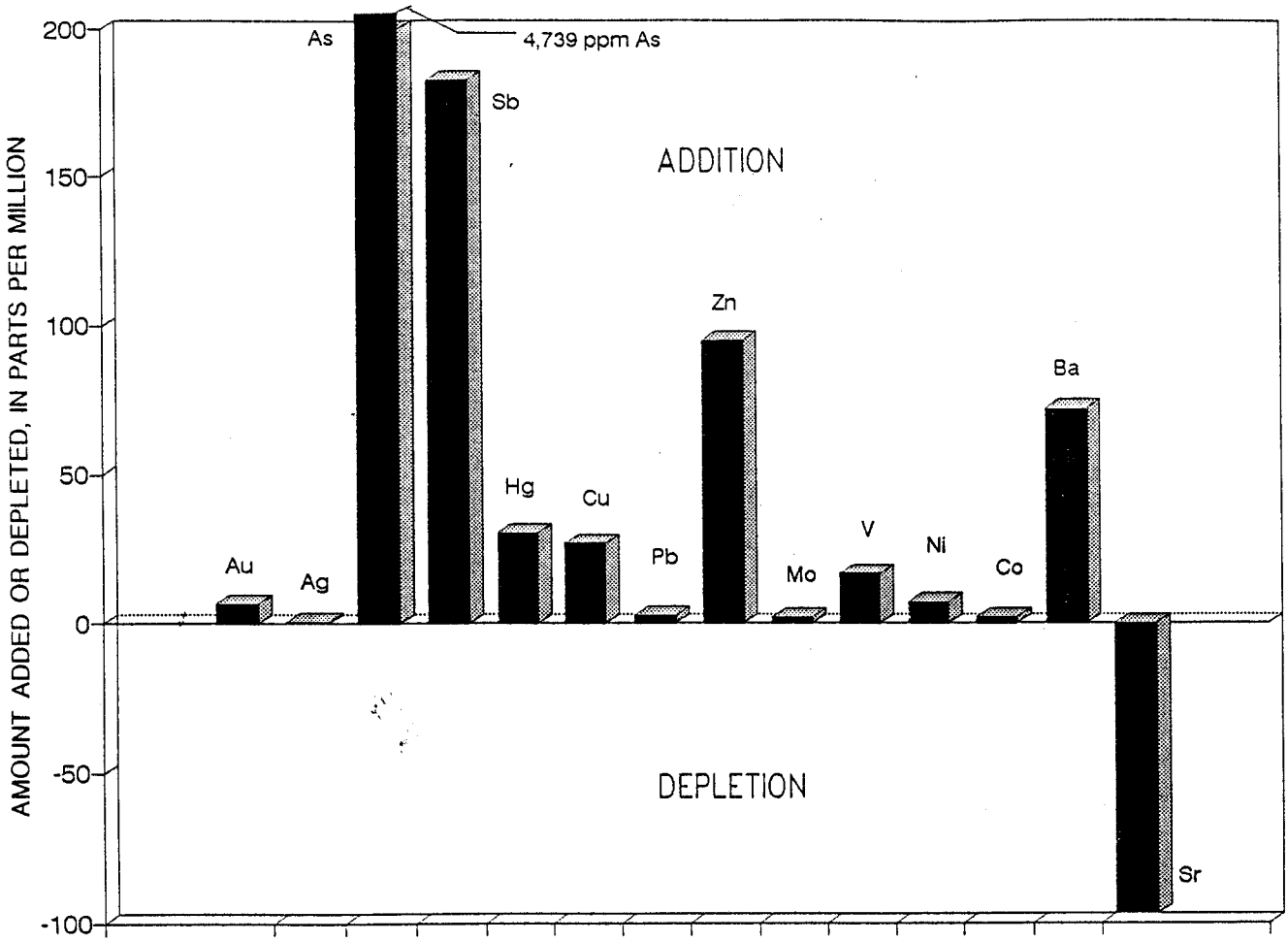

Figure 3. Trace-element addition and depletion associated with gold mineralization in the Comus Formation.

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