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Data on the Geochemistry of Carlin-type Disseminated Gold Deposits and Associated Rocks, Northcentral Nevada

by

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INTRODUCTION

In June, 1984, 15 geologists from nine USGS branches and two universities participated in a multidisciplinary field trip to disseminated gold deposits at Horse Canyon, Gold Acres, and Carlin in northcentral Nevada (Fig. 1). The purposes of this field trip were to bring together organic geochemists and economic geologists to discuss, on the outcrop, the relationships between gold mineralization and the occurrence of organic-carbon-rich host rocks, and to collect samples for organic and inorganic geochemical analyses. Some preliminary results of analyses of samples collected on this field trip, as well as results of other studies of Carlin-type disseminated gold deposits, were presented at a workshop at the USGS National Training Center, Denver Federal Center, in February, 1985. The purpose of this report is to present sample descriptions, inorganic geochemical data, Rock-Eval pyrolysis data, and stable-carbon isotope data for the samples collected on the 1984 field trip. In addition to samples from the three localities mentioned above (hereafter referred to as the "DG84" samples), we also analyzed samples from the Vantage II pit at Alligator Ridge (Figure 1) provided by Robert P. Ilchik (referred to as the "V2" samples); from Jerritt Canyon, Gold Acres, Cortez, and Alligator Ridge (Figure 1) provided by David L. Giles (referred to as the "DLG" samples); and from the unmineralized Woodruff Formation (Devonian) collected on the 1984 field trip in Cole Creek Canyon south of Carlin (Figure 1). In all, the following formations were sampled: Vinini Formation (Ordovician), Hanson Creek Formation (Middle Ordovician to Lower Silurian), Wenban Limestone (Devonian), Popovich Formation (Devonian), Roberts Mountains Formation (Lower Silurian to Lower Devonian), Woodruff Formation (Devonian), and Pilot Shale (Devonian and Mississippian).

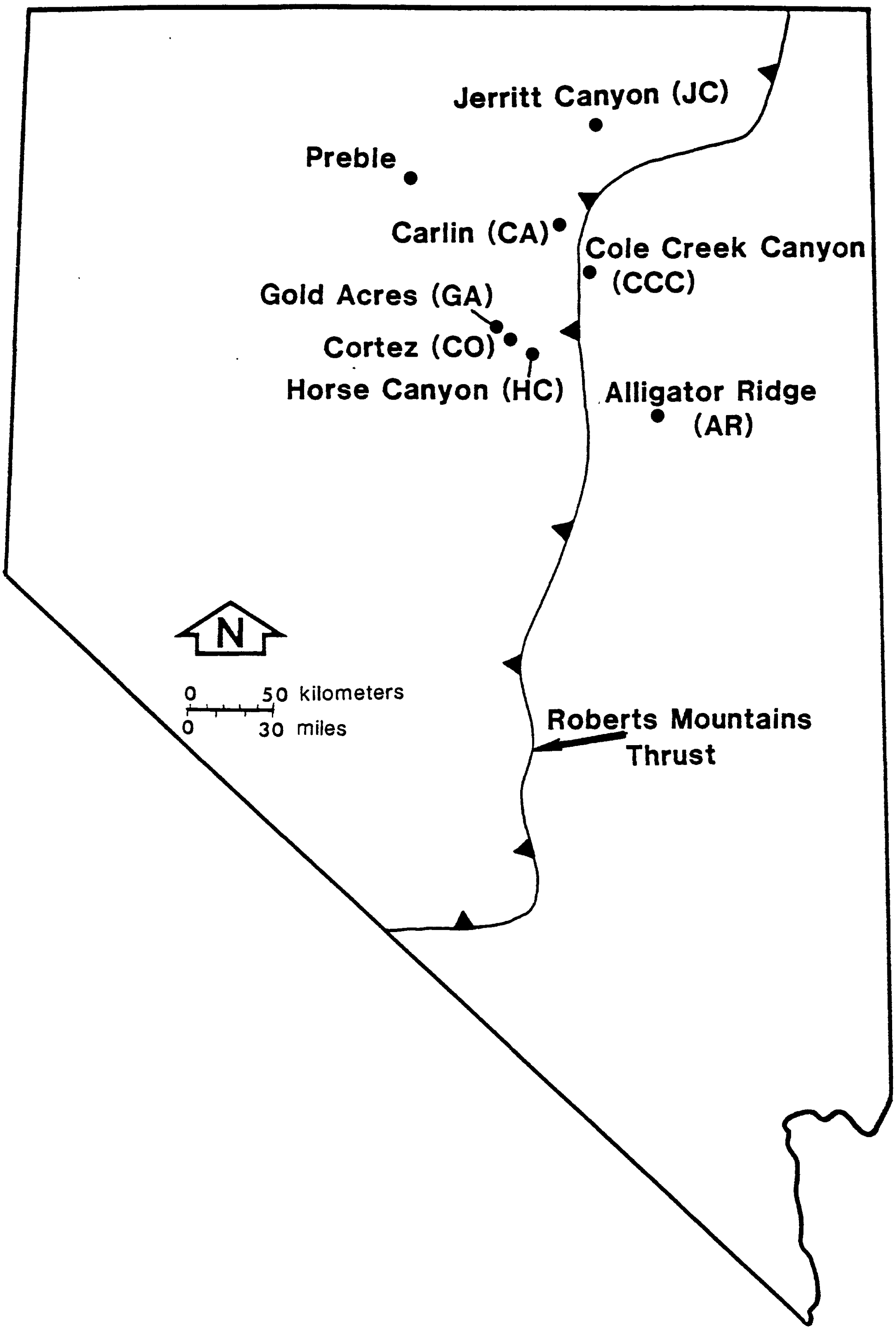

Figure 1. Map of Nevada showing the position of the Roberts Mountains thrust fault and the sample localities discussed in this report.

DESCRIPTION OF SAMPLES

DG84-03--Horse Canyon, south pit, 8,120-ft. level; Wenban Limestone dark gray carbonate.

DG84-04--Horse Canyon, south pit, 8,120-ft. level; black pod of sooty, pyritized material in Wenban Limestone near sample DG84-03.

DG84-05--Horse Canyon, south pit, 8,000-ft. level; black pod of sooty material containing pervasive slickensides in Wenban Limestone.

DG84-06--Horse Canyon, south pit, 8,020-ft. level; black pod of sooty, pyritized material with unusual honeycombed structure that is in sharp contact with "normal" Wenban Limestone country rock.

DG84-07o--Horse Canyon, south pit, 8,000-ft. level; oxidized part of sample of Wenban Limestone containing oxidized/carbonized ore boundary.

DG84-07c--Horse Canyon, south pit, 8,120-ft. level; carbonized part of sample GD84-07o.

DG84-08--Gold Acres, London extension, west wall; black pod of sooty material with metallic sheen in the Roberts Mountains Formation.

DG84-09--Gold Acres, London extension, west wall; sample of typical Roberts Mountains Formation country rock about 1 m above sample DG84-08.

DG84-10--Gold Acres, main pit; black pod of sooty, pyritized material that is pervasively riddled with gypsum in Vinini Formation.

DG84-11--Carlin, old main pit, 6,440-ft level; large pod of black, argillaceous material with resinous material filling crack in Vinini Formation.

DG84-12--Carlin, old main pit, 6,160-ft level; silicified Roberts Mountains Formation; dark-gray, bioturbated argillite.

DG84-13o--Carlin, old main pit, 6,160-ft level; oxidized part of sample of silicified Roberts Mountains Formation containing oxidized/carbonized ore boundary.

DG84-13c--Carlin, old main pit, 6,160-ft level; carbonized part of sample DG84-13o.

DG84-14--Carlin, old main pit, 6,160-ft level; Roberts Mountains Formation; yellowish-orange argillite with distinct burrow structures.

DG84-16--Carlin, old main pit, 6,280-ft level; dike-like mass of soft, friable, sooty material in Popovich Formation.

DG84-19--Cole Creek Canyon; Woodruff Formation; laminated organic-rich shale.

DG84-20--Cole Creek Canyon; Woodruff Formation; low-density, brownish rock near sample DG84-19.

DG84-21--Cole Creek Canyon; Woodruff Formation; low-density, finely laminated shale.

DG84-22--Cole Creek Canyon; Woodruff Formation; hard, dense, dark-gray nodule within shale samples by DG84-21.

V2-3458--Alligator Ridge, Vantage II pit; unmineralized Pilot Shale about 25 ft. from mineralized zone.

V2-3572--Alligator Ridge, Vantage II pit; mineralized carbonaceous Pilot Shale.

DLG-ARDP--Alligator Ridge; Pilot Shale
DLG-CSRM--Cortez; Roberts Mountains Formation
DLG-GADV--Gold Acres; Vinini Formation
DLG-JCOHC--Jerritt Canyon; Hansen Creek Formation
DLG-JCSRM--Jerritt Canyon; Roberts Mountains Formation

ANALYTICAL METHODS

The samples were air-dried and ground to pass a 100-mesh (149 um) sieve. Concentrations of 33 major, minor, and trace elements (Al, Fe, Mg, Ca, Na, K, Ti, P, Mn, Ag, As, Ba, Be, Cd, Ce, Co, Cr, Cu, Ga, La, Li, Mo, Nb, Nd, Ni, Pb, Sc, Sr, Th, V, Y, Yb, and Zn) were determined in all samples by inductively coupled, argon-plasma emission spectrometry (ICP). Concentrations of 10 major elements (Si, Al Fe, Mg, Ca, Na, K, Ti, P, and Mn) were also determined in the five DLG samples by X-ray fluorescence (XRF) with excellent agreement between XRF and ICP results. Concentrations of As, Au, and Sb were determined in 11 of the DG84 samples by neutron activation analysis (INAA). Concentrations of Ag and Au in the DLG samples were determined by fire assay. Concentrations of Hg, Sb, and Tl in the DLG samples were determined by atomic absorption spectrophotometry (AAS). Concentrations of total sulfur, and total carbon were determined using LECO combustion-infrared instrumentation. Carbonate carbon was determined by coulometric titration of acid-evolved CO_2, and organic carbon was calculated as the difference between total carbon and carbonate carbon. All of the methods listed above are described in Baedecker (1987).

Organic geochemical properties based on pyrolysis were measured with a Rock-Eval instrument that was calibrated by analysis of reference rock samples, a synthetic standard ($n\text{-}C_{20}H_{42}$), and CO_2 gas. The Rock-Eval pyrolysis method provides a rapid determination of the hydrocarbon (HC) yield and degree of alteration of sedimentary organic matter (Espitalie and others, 1977; Peters, 1986), and is a convenient method for screening samples for additional organic geochemical methods. Hydrocarbons are liberated from a powdered rock sample by programmed heating up to 550° C and are measured with a flame ionization detector. Free or adsorbed hydrocarbons are liberated by heating the sample in flowing helium at a relatively low temperature (250° C) for 5 min., and the yield is recorded as the area under the first peak on a pyrogram (S_1; mgHC/g rock). The S_1 yield is roughly proportional to the content of organic compounds that can be extracted from the rock with organic solvents. The second peak on the pyrogram is produced by thermal breakdown of kerogen and, to a small degree, by cracking of resins and asphaltines as the sample is heated from 250° to 550° C (S_2; mgHC/g rock). CO_2 also is generated by kerogen degradation and is retained during the heating interval from 250° to 390° C and is reported as the integrated area under the third peak on the pyrogram (S_3; mg CO_2/g rock). Our Rock-Eval results are expressed as a hydrogen index (HI) in mg HC/g OC, which is the S_2 value normalized to amount of organic carbon (OC) present, an oxygen index (OI) in mgCO_2/g OC, which is the S_3 normalized to OC content of the sample, and a temperature of maximum hydrocarbon yield (Tmax) (Tissot and Welte, 1978). Tmax can be roughly correlated with maximum temperature to which the rock has been exposed, and is interpreted as a measure of the thermal maturity of the organic matter (Tissot and Welte, 1978). Unfortunately, an accurate value of Tmax is difficult to obtain for samples with low hydrocarbon yields (i.e low values of HI). Values of HI and OI generally correlate well with atomic H/C ratios, respectively, measured by other methods in the same samples (Espitalie and others, 1977; Tissot and Welte, 1978).

Stable carbon-isotope ratios were determined by standard techniques (Kaplan and others, 1970; Pratt and Threlkeld, 1984). Powdered samples were oven dried at 40° C and reacted with a large volume of 0.5% HCl. The insoluble residue was centrifuged, decanted, washed with deionized water, dried under flowing nitrogen at 50°, and combusted at 1000° under oxygen pressure in a LECO induction furnace. The resulting CO_2 was dehydrated and purified in a high-vacuum cryogenic gas-transfer system, and the isotope ratios determined with a Finnigan MAT 251 6-inch, 90°-sector, isotope-ratio mass spectrometer. Results are reported in the usual per mil δ-notation relative to the Peedee belemnite marine-carbonate standard (PDB):

$$\delta^{13}C\ (^{o}/oo) = [(R_{sample}/R_{PDB})-1] \times 10^3$$

where R is the ratio ^{13}C to ^{12}C.

ANALYTICAL RESULTS

Inorganic Geochemistry

Results of geochemical analyses of the DG84, V2, and DLG samples are given in Table 1. Summary statistics for all samples are given in Table 2. In order to isolate anomalous concentrations of elements, it woulds be useful to compare the results in Tables 1 and 2 to some standard reference material. Because most of the host rocks of Carlin-type gold deposits are fine-grained sedimentary rocks, we chose the composition of average shale as reported by Turekian (1972) as one reference material. For a second reference material, we chose average upper continental crust as reported by Wedepohl (1971). Figure 2 contains log-log plots of concentrations of major and trace elements in the average of our DG84, V2, and DLG samples (Table 2) versus average shale and average crust. The most obvious features of Figure 2 are the very high (more than ten-fold) concentrations of As, Mo, and S relative to average crust, and the high (up to five fold) concentrations of V, Zn, and Ni. The high concentrations of Ca and Mg in the Carlin rocks are expected because several of the host rock units are carbonates. Also notable are the low concentrations (more than five-fold depletion) of Na and Mn. Differences in trace-element concentrations between our Carlin samples and average shale are not as large because most shales are enriched in many trace elements, especially the siderophile and chalcophile elements, relative to average crust.

Table 1. Geochemical analyses of Carlin-type old ores and associated rocks, northcentral Nevada.
[An "L" to the right of a value indicates that concentration is less than that value. Dashes (--) indicate no analysis]

Sample	% Al_2O_3	% Fe_2O_3	% MgO	% CaO	% Na_2O	% K_2O
DG84-03	2.85	1.06	2.32	44.80	0.03	0.83
DG84-04	4.18	2.00	8.79	30.80	0.04	1.32
DG84-05	12.85	11.58	1.04	0.03	0.07	3.84
DG84-06	14.44	0.69	1.11	0.10	0.07	3.96
DG84-07c	6.42	2.29	8.79	28.00	0.05	1.68
DG84-07o	6.61	2.43	8.29	28.00	0.05	1.68
DG84-08	5.89	2.00	9.28	19.60	0.03	1.92
DG84-09	5.89	1.72	11.44	21.00	0.03	1.80
DG84-10	3.80	1.19	3.65	10.36	0.01	1.14
DG84-11	2.27	0.87	0.58	2.10	0.04	0.42
DG84-12	6.46	1.86	9.12	21.00	0.04	2.04
DG84-13c	6.42	1.86	8.79	21.00	0.04	2.04
DG84-13o	7.74	2.14	8.62	16.80	0.03	2.40
DG84-14	9.44	2.57	6.80	9.10	0.04	2.76
DG84-16	8.88	3.00	0.73	2.52	0.04	1.92
DG84-19	5.89	2.43	11.11	18.20	0.07	2.04
DG84-20	11.40	1.86	1.29	0.15	0.30	3.24
DG84-21	5.70	1.86	7.63	11.34	0.22	2.04
DG84-22	3.21	0.92	7.96	22.40	0.08	0.94
V2-3458	11.33	4.43	1.01	0.13	0.08	2.52
V2-3572	10.01	4.00	1.03	0.22	0.05	2.52
DLG-ARDP	11.89	4.37	1.25	0.20	0.07	3.54
DLG-CSRM	7.23	2.95	0.68	0.13	0.01	2.36
DLG-GADV	4.43	7.81	0.44	1.19	0.01L	1.29
DLG-JCOH	2.40	0.99	2.17	39.18	0.04	0.79
DLG-JCSR	4.55	1.40	11.80	19.29	0.03	1.48

Table 1. (Continued)

Sample	% TiO_2	% P_2O_5	% MnO	ppm Ag	ppm As	oz/Ton Au
DG84-03	0.05	0.05	0.057	2.00L	--	--
DG84-04	0.05	0.05	0.053	2.00L	--	--
DG84-05	0.25	0.01L	0.003	2.00L	2010.00	0.1171
DG84-06	0.28	0.05	0.001	2.00L	--	--
DG84-07c	0.10	0.07	0.032	2.00L	60.00	0.0003
DG84-07o	0.15	0.07	0.030	2.00L	52.90	0.01
DG84-08	0.23	0.11	0.083	2.00L	--	--
DG84-09	0.23	0.07	0.080	2.00L	--	--
DG84-10	0.10	0.09	0.050	2.00L	--	--
DG84-11	0.08	0.62	0.005	2.00L	4.71	0.0000L
DG84-12	0.23	0.11	0.034	2.00L	--	--
DG84-13c	0.23	0.07	0.028	2.00L	46.80	0.0000L
DG84-13o	0.27	0.09	0.034	2.00L	2.32	0.0005
DG84-14	0.35	0.11	0.033	2.00L	370.00	0.0000L
DG84-16	0.28	1.56	0.003	3.00	195.00	0.0005
DG84-19	0.22	0.11	0.017	2.00L	--	--
DG84-20	0.47	0.16	0.002	2.00L	--	--
DG84-21	0.22	0.14	0.011	2.00L	--	--
DG84-22	0.13	0.23	0.010	3.00	80.30	0.0000L
V2-3458	0.43	0.16	0.065	2.00L	293.00	0.0002
V2-3572	0.40	0.16	0.010	2.00	3150.00	0.6464
DLG-ARDP	0.63	0.18	0.008	3.13L	4200.00	0.08
DLG-CSRM	0.32	0.06	0.003	3.13L	1800.00	0.10
DLG-GADV	0.18	0.19	0.002	6.25	3600.00	0.19
DLG-JCOH	0.07	0.06	0.036	3.13L	90.00	0.01L
DLG-JCSR	0.22	0.05L	0.023	3.13L	40.00	0.01L

Table 1. (Continued)

Sample	ppm Ba	ppm Be	ppm Cd	ppm Ce	ppm Co	ppm Cr
DG84-03	310.00	1.00L	2.00L	19.00	4.00	21.00
DG84-04	530.00	1.00L	2.00L	18.00	6.00	33.00
DG84-05	1000.00	2.00	2.00L	39.00	10.00	95.00
DG84-06	990.00	1.00	2.00L	72.00	1.00L	110.00
DG84-07c	290.00	1.00L	2.00L	28.00	7.00	44.00
DG84-07o	280.00	1.00L	2.00L	29.00	4.00	46.00
DG84-08	84.00	1.00	3.00	61.00	5.00	62.00
DG84-09	83.00	1.00	2.00L	30.00	5.00	46.00
DG84-10	58.00	1.00L	2.00L	11.00	2.00	36.00
DG84-11	1100.00	1.00L	2.00L	16.00	4.00	27.00
DG84-12	200.00	1.00L	2.00L	38.00	8.00	58.00
DG84-13c	250.00	1.00L	2.00L	34.00	7.00	49.00
DG84-13o	1100.00	1.00L	2.00L	39.00	9.00	51.00
DG84-14	230.00	1.00	2.00L	44.00	11.00	76.00
DG84-16	3800.00	1.00L	2.00L	52.00	10.00	200.00
DG84-19	1700.00	1.00	8.00	38.00	7.00	64.00
DG84-20	300.00	3.00	3.00	78.00	2.00	120.00
DG84-21	330.00	1.00L	64.00	32.00	4.00	280.00
DG84-22	1000.00	1.00L	45.00	19.00	4.00	170.00
V2-3458	260.00	2.00	2.00	66.00	20.00	77.00
V2-3572	130.00	1.00	2.00L	57.00	16.00	73.00
DLG-ARDP	140.00	3.00	2.00L	61.00	27.00	75.00
DLG-CSRM	86.00	2.00	2.00L	28.00	8.00	51.00
DLG-GADV	45.00	1.00L	2.00L	8.00	32.00	19.00
DLG-JCOH	130.00	1.00L	2.00L	14.00	4.00	11.00
DLG-JCSR	180.00	1.00	3.00	11.00	6.00	63.00

Table 1. (Continued)

Sample	ppm Cu	ppm Ga	ppm La	ppm Li	ppm Mo	ppm Nb
DG84-03	7.00	4.00L	8.00	9.00	2.00L	--
DG84-04	7.00	5.00	7.00	10.00	2.00L	--
DG84-05	25.00	19.00	24.00	15.00	39.00	4.00L
DG84-06	12.00	18.00	46.00	18.00	14.00	--
DG84-07c	17.00	8.00	16.00	15.00	8.00	8.00
DG84-07o	11.00	9.00	16.00	15.00	9.00	8.00
DG84-08	49.00	6.00	48.00	10.00	77.00	--
DG84-09	65.00	8.00	20.00	8.00	39.00	--
DG84-10	12.00	5.00	7.00	8.00	23.00	--
DG84-11	13.00	4.00L	11.00	9.00	5.00	4.00L
DG84-12	20.00	9.00	21.00	20.00	2.00L	--
DG84-13c	13.00	9.00	19.00	20.00	2.00L	9.00
DG84-13o	19.00	11.00	22.00	21.00	2.00L	9.00
DG84-14	23.00	13.00	27.00	31.00	2.00L	8.00
DG84-16	140.00	13.00	48.00	36.00	17.00	7.00
DG84-19	73.00	6.00	27.00	17.00	75.00	--
DG84-20	72.00	15.00	61.00	28.00	91.00	--
DG84-21	260.00	5.00	43.00	24.00	77.00	--
DG84-22	160.00	4.00L	29.00	18.00	92.00	6.00
V2-3458	43.00	14.00	38.00	41.00	38.00	6.00
V2-3572	23.00	15.00	31.00	59.00	63.00	4.00L
DLG-ARDP	47.00	20.00	38.00	62.00	45.00	6.00
DLG-CSRM	38.00	11.00	19.00	23.00	17.00	4.00L
DLG-GADV	65.00	10.00	3.00	33.00	10.00	4.00L
DLG-JCOH	14.00	4.00L	11.00	9.00	2.00L	4.00L
DLG-JCSR	32.00	5.00	14.00	16.00	11.00	4.00

Table 1. (Continued)

Sample	ppm Nd	ppm Ni	ppm Pb	ppm Sc	ppm Sr	ppm Th
DG84-03	7.00	12.00	4.00L	2.00L	680.00	4.00L
DG84-04	9.00	29.00	10.00	6.00	160.00	4.00L
DG84-05	14.00	71.00	12.00	12.00	17.00	11.00
DG84-06	29.00	6.00	18.00	11.00	25.00	8.00
DG84-07c	15.00	38.00	16.00	6.00	190.00	4.00
DG84-07o	16.00	29.00	18.00	6.00	190.00	4.00
DG84-08	30.00	86.00	9.00	6.00	170.00	4.00L
DG84-09	17.00	58.00	7.00	5.00	200.00	4.00L
DG84-10	7.00	25.00	7.00	4.00	100.00	4.00L
DG84-11	12.00	50.00	4.00L	2.00	94.00	4.00L
DG84-12	20.00	35.00	8.00	6.00	160.00	5.00
DG84-13c	22.00	27.00	7.00	5.00	200.00	4.00L
DG84-13o	19.00	31.00	10.00	7.00	110.00	6.00
DG84-14	23.00	45.00	7.00	9.00	68.00	8.00
DG84-16	39.00	220.00	11.00	7.00	120.00	8.00
DG84-19	25.00	160.00	13.00	6.00	230.00	5.00
DG84-20	53.00	150.00	17.00	10.00	530.00	6.00
DG84-21	46.00	430.00	10.00	8.00	160.00	4.00L
DG84-22	39.00	400.00	9.00	5.00	240.00	4.00L
V2-3458	31.00	150.00	21.00	7.00	590.00	10.00
V2-3572	26.00	140.00	13.00	7.00	290.00	9.00
DLG-ARDP	26.00	210.00	17.00	12.00	670.00	10.00
DLG-CSRM	15.00	40.00	64.00	5.00	13.00	5.00
DLG-GADV	6.00	120.00	38.00	5.00	5.00	4.00L
DLG-JCOH	11.00	9.00	4.00	2.00L	590.00	4.00L
DLG-JCSR	9.00	37.00	11.00	4.00	110.00	4.00L

Table 1. (Continued)

Sample	ppm V	ppm Y	ppm Yb	ppm Zn	ppm Sb	% Total S
DG84-03	15.00	8.00	1.00L	9.00	--	--
DG84-04	26.00	9.00	2.00	7.00	--	--
DG84-05	79.00	11.00	1.00	150.00	589.00	2.58
DG84-06	100.00	11.00	1.00	4.00L	--	--
DG84-07c	50.00	16.00	1.00	36.00	6.24	0.04
DG84-07o	53.00	16.00	1.00	33.00	3.71	0.02
DG84-08	430.00	27.00	2.00	36.00	--	--
DG84-09	230.00	26.00	2.00	52.00	--	--
DG84-10	250.00	9.00	1.00	110.00	--	--
DG84-11	120.00	22.00	1.00	130.00	1.60	0.52
DG84-12	78.00	21.00	2.00	6.00	--	--
DG84-13c	47.00	23.00	2.00	38.00	2.26	0.68
DG84-13o	61.00	24.00	2.00	93.00	25.20	0.04
DG84-14	95.00	18.00	2.00	120.00	18.90	0.01
DG84-16	730.00	70.00	4.00	190.00	31.30	1.29
DG84-19	890.00	41.00	3.00	62.00	--	--
DG84-20	1700.00	51.00	5.00	86.00	--	--
DG84-21	6500.00	64.00	7.00	2300.00	--	--
DG84-22	3500.00	80.00	6.00	2900.00	44.80	1.84
V2-3458	130.00	28.00	2.00	190.00	13.40	2.86
V2-3572	61.00	23.00	2.00	310.00	120.00	2.42
DLG-ARDP	120.00	28.00	2.00	120.00	85.00	2.68
DLG-CSRM	370.00	11.00	1.00	60.00	11.00	1.50
DLG-GADV	230.00	3.00	1.00L	30.00	16.00	6.10
DLG-JCOH	18.00	10.00	1.00L	30.00	1.00L	0.45
DLG-JCSR	480.00	16.00	1.00	190.00	3.00	0.80

Table 1. (Continued)

Sample	% org. C	% crb. C	H-index	O-Index	T-max	$\delta^{13}C_{org}$
DG84-03	--	--	--	--	--	--
DG84-04	--	--	--	--	--	--
DG84-05	1.49	0.01L	--	--	--	-24.2
DG84-06	--	--	--	--	--	--
DG84-07c	0.60	8.02	--	--	--	-24.1
DG84-07o	0.04	8.13	--	--	--	-22.8
DG84-08	--	--	--	--	--	--
DG84-09	--	--	--	--	--	--
DG84-10	--	--	--	--	--	--
DG84-11	2.03	2.55	--	--	--	-30.0
DG84-12	--	--	--	--	--	--
DG84-13c	0.25	5.65	--	--	--	-29.0
DG84-13o	0.20	5.41	--	--	--	-28.9
DG84-14	0.09	3.61	--	--	--	-30.8
DG84-16	10.60	0.44	--	--	--	-30.7
DG84-19	--	--	--	--	--	--
DG84-20	--	--	--	--	--	--
DG84-21	--	--	--	--	--	--
DG84-22	15.00	5.53	430	9	435	-31.7
V2-3458	2.80	0.16	20	--	432	-29.9
V2-3572	3.26	0.12	27	--	442	-29.0
DLG-ARDP	1.97	0.02	14	8	512	-29.6
DLG-CSRM	0.60	0.01L	8	25	519	-23.6
DLG-GADV	0.52	0.05	350	30	496	-24.0
DLG-JCOH	0.22	8.62	--	127	437	-27.1
DLG-JCSR	1.19	7.43	35	25	342	-28.7

Table 2.--Summary statistics analyses of Carlin-type gold ores and related rocks, northcentral Nevada.
[N is the total number of samples out of 26 for which an analysis was made for a particular element or oxide; N* is the number of observations greater than the lower limit of detection.]

Element or Oxide	Minimum	Maximum	Mean	Standard Deviation	N	N*
% SiO_2	21.7	80.4	--	--	5	5
% Al_2O_3	2.27	14.4	7.0	3.37	26	26
% Fe_2O_3	.69	11.5	2.7	.55	26	26
% MgO	.44	11.8	5.2	4.14	26	26
% CaO	.028	44.8	14.1	13.2	26	26
% Na_2O	<.007	.30	.06	.06	26	25
% K_2O	.42	3.96	2.02	.92	26	26
% TiO_2	.05	.63	.24	.14	26	26
% P_2O_5	<.01	1.56	.18	.30	26	24
% MnO	.001	.083	.025	.024	26	26
% T-S	.01	6.1	.91	1.44	16	16
% Org. C	.04	15.	1.57	3.49	16	16
% Carb. C	<.02	8.62	2.14	3.17	16	14
ppm Ag	<2	6	--	--	5	4
ppm As	<2	4200	615	1240	16	16
oz/T Au	<.1	.65	--	--	16	10
ppm Ba	45	3800	560	790	26	26
ppm Be	<1	3	--	--	26	12
ppm Cd	<2	64	--	--	26	7
ppm Ce	8	78	36	20	26	26
ppm Co	<1	32	9	7	26	25
ppm Cr	11	280	75	60	26	26
ppm Cu	7	260	48	58	26	26
ppm Ga	<4	20	10	5	26	22
ppm Hg	.03	12	--	--	5	5
ppm La	3	61	25	15	26	26
ppm Li	8	62	22	14	26	26
ppm Mo	<2	92	29	31	26	19
ppm Nb	<2	9	--	--	16	10
ppm Nd	6	53	22	12	26	26
ppm Ni	6	430	100	111	26	26
ppm Pb	<4	64	14	12	26	25
ppm Sb	<1	590	37	116	16	15
ppm Sc	<2	12	6	3	26	24
ppm Sr	5	680	230	205	26	26
ppm Th	<4	11	--	--	26	14
ppm Tl	.2	43	--	--	5	5
ppm V	15	6500	630	1400	26	26
ppm Y	3	80	26	20	26	26
ppm Yb	<.1	7	2	1.6	26	23
ppm Zn	<4	2900	280	690	26	25

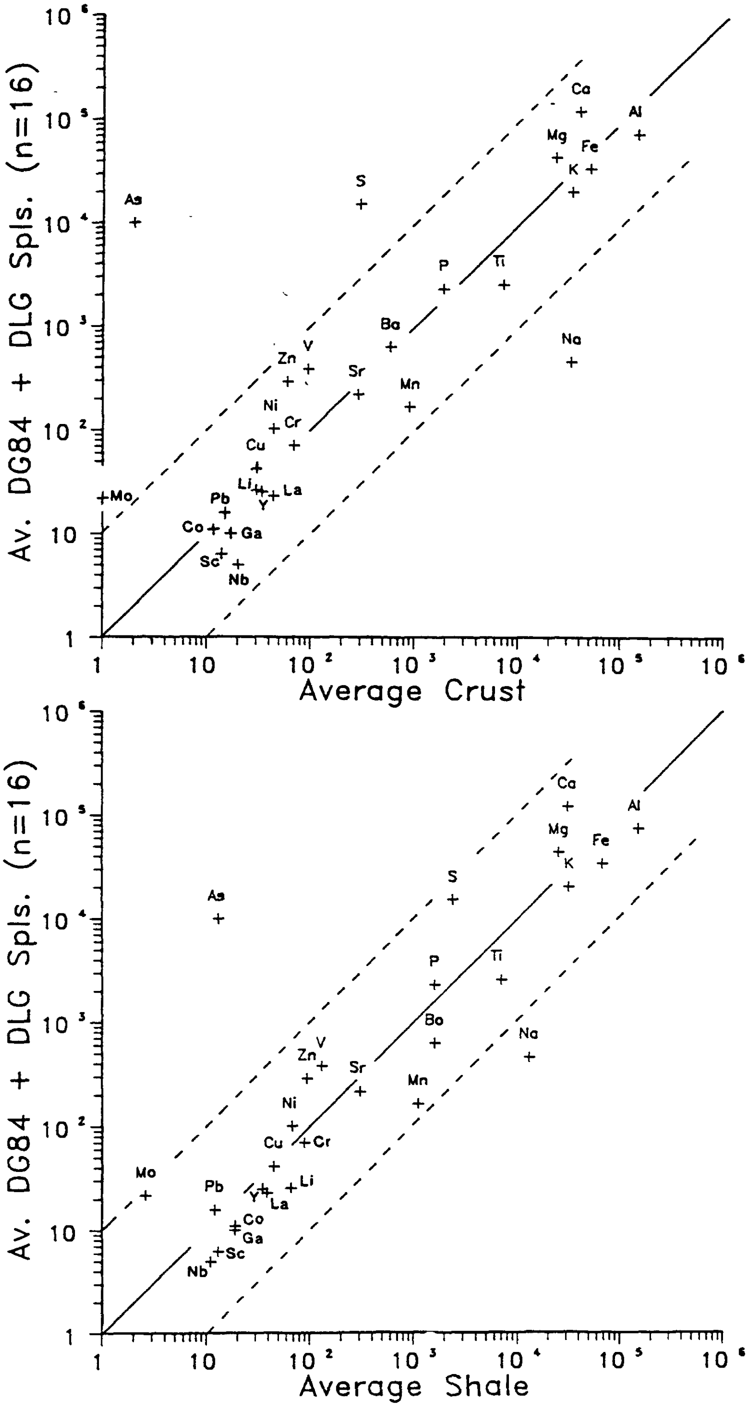

Figure 2. Log-log plots of concentrations, in parts per million, of major-element oxides and trace elements in: (A) average upper continental crust (Wedepohl, 1971) versus our average Carlin sample, and (B) average shale (Turekian, 1972) versus our average Carlin sample. Major elements are plotted as the oxide concentration although the element symbol is shown on the plot for simplicity. Solid line represents a ratio of 1:1 between concentration in average shale and average Carlin sample of major, and trace elements. Dashed lines are drawn at concentration ratios that are ten times greater and ten times less in average carlin sample relative to average crust or average shale.

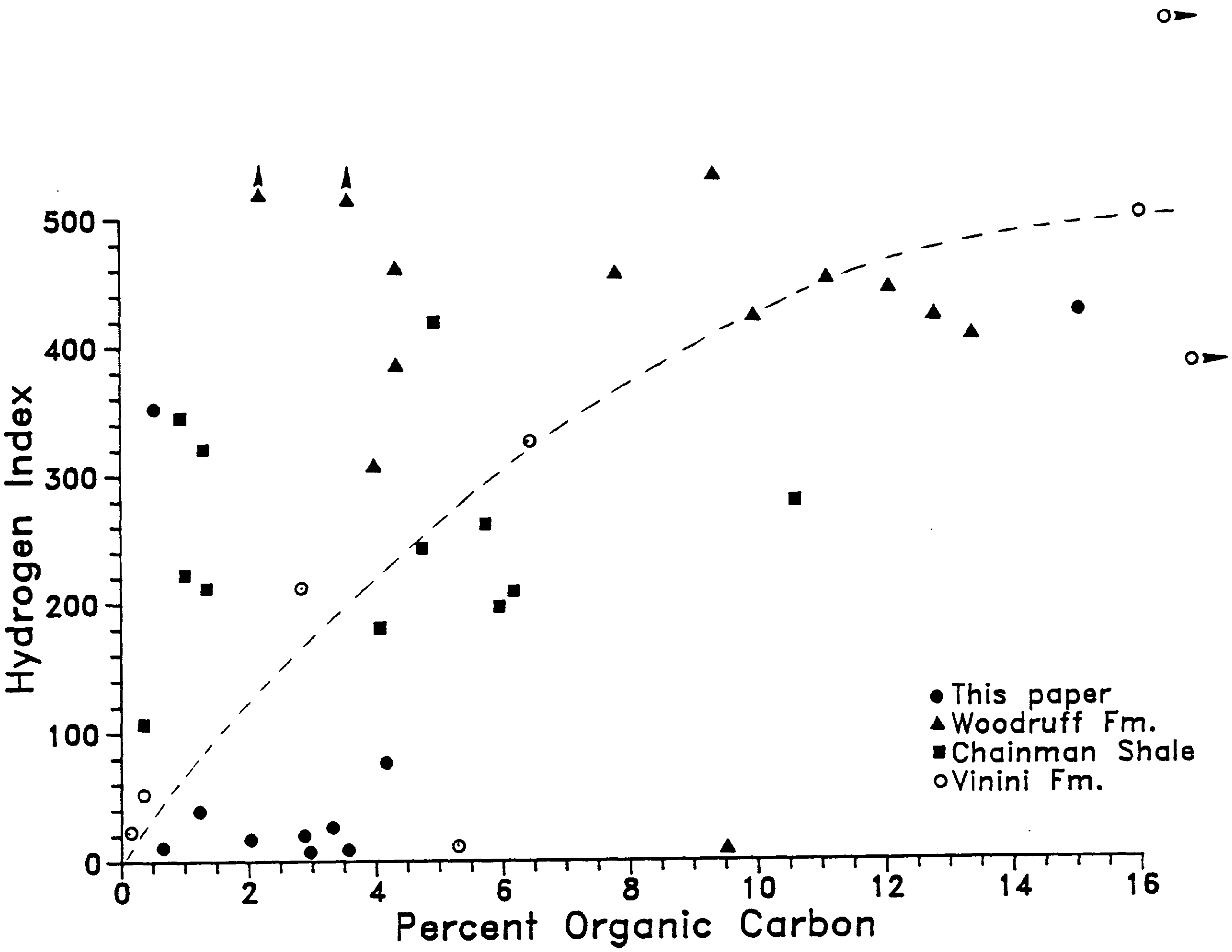

Figure 3. Scatter plot of percent organic carbon versus Rock-Eval hydrogen index (HI) for our samples of Carlin-type ores and associated rocks (Appendix I), and samples of Paleozoic rocks from the Great Basin reported by Poole and Claypool (1985). Dashed curve is an approximate average relation between organic carbon and HI for Cretaceous black shales that have not been thermally altered (Dean and others, 1986).

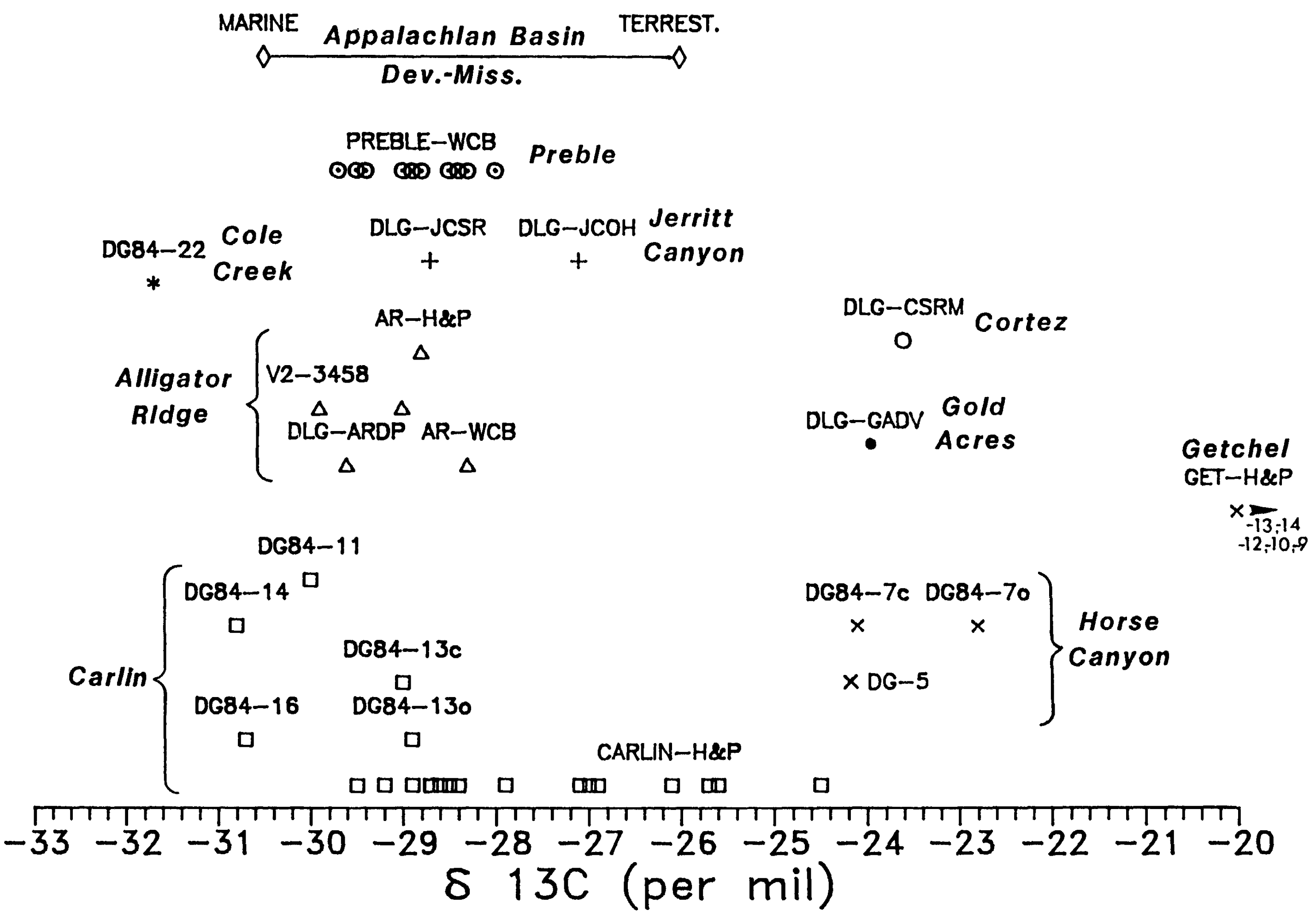

Figure 4. Values of $\delta^{13}C$ for organic matter in samples of Carlin-type ores and related rocks. Range of values for organic matter in Devonian-Mississippian black shales from the Appalachian basin (Maynard, 1981) are shown for comparison.

Organic Geochemistry

Rock-Eval Pyrolysis

Results of Rock-Eval hydrocarbon yield, expressed as HI, are plotted versus % OC in Figure 3. Unfortunately, most samples have been highly altered and have very low hydrocarbon yields. For comparison, examples of values of HI and % OC for Paleozoic OC-rich strata of relatively low thermal maturity from central Nevada reported by Poole and Claypool (1985) are included in Figure 3. The dashed curve in Figure 3 illustrates a typical relation between OC and HI observed in many data sets of Cretaceous samples at low thermal maturity (for example, see Dean and others, 1986). The data from Nevada Paleozoic samples show a tendency to fit along the same trend as the dashed line, but there is considerable scatter that probably is due mainly to varying degrees of thermal maturity. We suspect that most of the carbonaceous host rocks for Carlin-type disseminated gold deposits originally contained an abundance of H-rich organic matter such as that found in the less altered Paleozoic samples. Our black shale samples from the Woodruff Formation (Devonian) in Cole Creek Canyon just south of Carlin probably have characteristics similar to most of the Paleozoic host rocks prior to thermal alteration.

Carbon Isotope Ratios

Results of stable-carbon isotope analyses of organic carbon in samples from outcrop and mine localities in northcentral Nevada (Table 1) are plotted in Figure 4. Also shown in Figure 4 are the results of analyses of samples from Preble and Alligator Ridge provided by William C. Bagby, and results of analyses of samples of Devonian-Mississippian black shales from the Appalachian basin (Maynard, 1981). The most striking feature of this plot is the bimodal distribution of values; with few exceptions, values of $\delta^{13}C$ are either isotopically light (between -28 to -32 $^{o}/oo$) or isotopically heavy (greater than about $-24^{o}/oo$). The heavy group of values are samples from Horse Canyon, Gold Acres, and Northumberland. The heaviest values are at least 2.0 $^{o}/oo$ less negative than the heaviest values from Maynard's (1981) Appalachian basin samples.

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