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Data on the Geochemistry and Thermal Maturation of Sedimentary-Rock Hosted, Disseminated Gold Deposits and Associated Rocks, Southwestern Guizhou Province, People's Republic of China

by

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INTRODUCTION

Five sedimentary-rock hosted disseminated gold deposits were recently discovered in southwestern Guizhou Province of the People's Republic of China. In September 1986, Charles G. Cunningham, Roger P. Ashley, and I-Ming Chou were the first foreign geologists permitted to visit the Yata, Getang, Sanchahe, and Ceyang deposits. They were accompanied by Huang Zushu of the Ministry of Geology and Mineral Resources (Beijing), Wan Chaoyuan of the Bureau of Geology and Mineral Resources of Guizhou Province (Guiyang), and Li Wenkang of the Shenyang Institute of Geology and Mineral Resources (Shenyang). Our Chinese colleagues provided complete access to the deposits, mine maps, drill cores, and samples. A suite of samples was collected from the Yata, Getang, and Sanchahe deposits to characterize the ores and to have a basis to compare the geochemical signature of these deposits with sedimentary-rock hosted (Carlin-type), disseminated gold deposits of the western United States. Some samples were selected to allow examination of the geochemical changes in hydrothermally altered host rocks peripheral to the deposit. The locations of the deposits relative to the principal cities in the Peoples's Republic of China are shown in Figure 1, and in more detail in their paleodepositional settings in Figure 2.

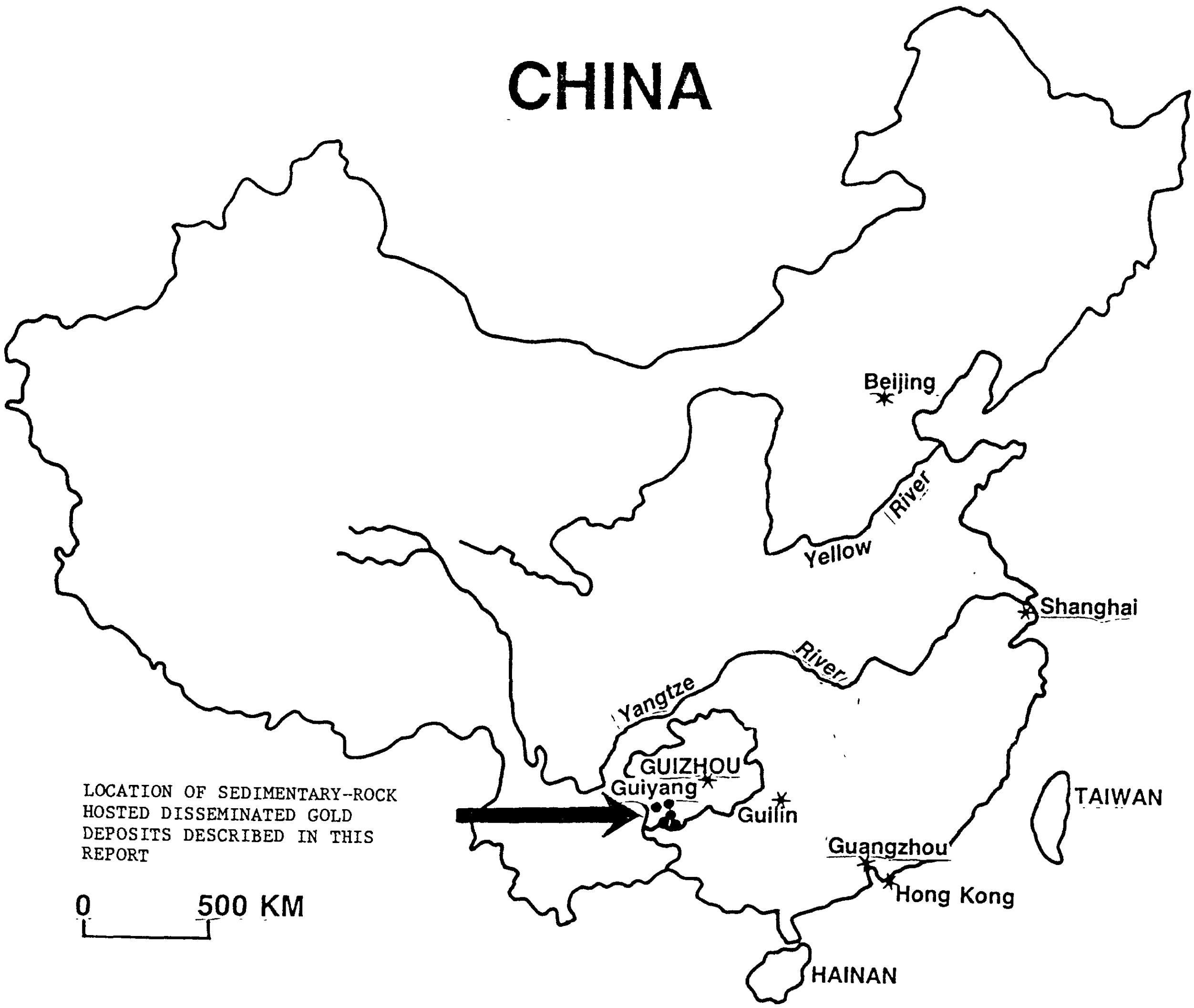

Figure 1.--Map of the People's Republic of China showing the location of the newly discovered sedimentary-rock hosted disseminated gold deposits in southwestern Guizhou Province (solid circles). Principal cities (stars) are given for reference.

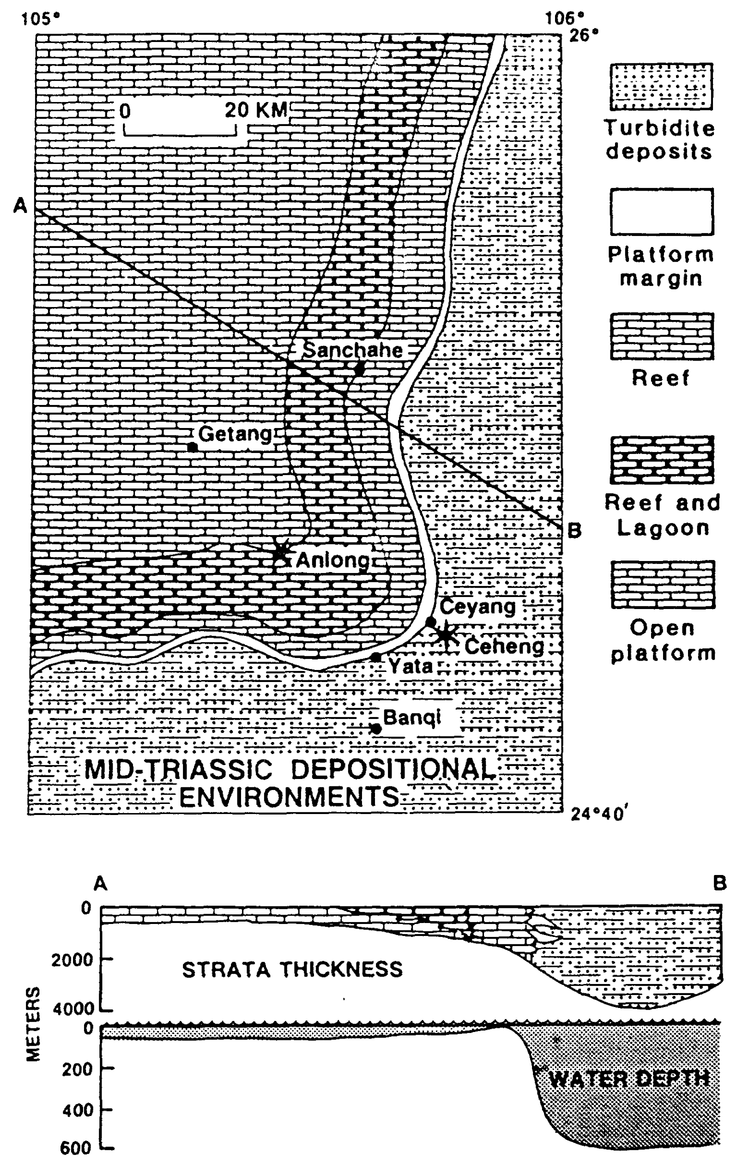

Figure 2.--Middle-Triassic depositional environments for rocks that host disseminated gold deposits in Guizhou Province. Strata thickness and interpreted water depth, indicating the position of the buried margin of the Precambrian Yangtze craton, are shown. The locations of the newly discovered deposits (solid circles) and principal towns (stars) are shown.

DESCRIPT'I ON OF SAMPLES

Yata Deposit

C-01A--Mineralized pyrite-bearing, carbonaceous shale of the middle Triassic Xinyuan Formation, host rock of the Yata deposit. Sample is cut by veins of realgar, quartz, and calcite. Sample is from dump of the 940-m (elevation) tunnel.

C-01B--Unmineralized carbonaceous shale of the middle Triassic Xinyuan Formation from same hand specimen as sample C-01A.

C-01C--Duplicate of sample C-01B.

C-02A--Mineralized carbonaceous shale of the middle Triassic Xinyuan Formation, host rock of the Yata deposit. Sample is cut by veins of realgar and quartz. Sample is from the dump of the 997-m (elevation) tunnel.

C-03A--Black carbonaceous shale of the Xinyuan Formation intimately associated with the ore zone. Sample contains some realgar and pyrite. Sample is from the 997-m tunnel.

C-04A--Black carbonaceous shale of the Xinyuan Formation collected about 100 m away from the main ore zone in the 670-m tunnel.

C-05A--Carbonaceous shale and carbonate at the base of the Xinyuan Formation. Sample colleced near the village of Yata, 4 km from the mine.

Getang Deposit

C-06A--Brecciated carbonaceous shale from 29.8 to 31.0 m depth in a core of the Upper Permian Longtan Formation, host rock of the Getang Deposit. Assay of shale from this interval is 11 g gold/ton.

C-07A--Low-grade coal from 19.8 to 20.0 m in same core of the Longtan Formation as sample C-06A.

C-08A--Jasperoid (silicified limestone) with leached pyrite from about 100 m above the orebody at the top of Two-Dragon Mouth Hill.

C-08B--Duplicate of sample C-08A.

C-09A--Silicified, brecciated carbonate(?) rock from the discovery trench of the Getang deposit. Sample is from the ore zone.

C-10A--Low-grade coal from bed about one-meter thick in the ore zone.

C-11A--Organic-rich shale from bed about 4 m above the ore zone. Coaly shale appears to be at the same stratigraphic horizon as that sampled by C-10A but from across the valley.

C-12A--Coal bed in the Longtan Formation that is actively being mined for coal. Coal bed is about 50m above ore zone at the mine.

C-13A--Coal from bed about 200 m above the mineralized zone and 2 km from the ore deposit.

Sanchahe Deposit

C-14A--Limonite-stained, silicified limestone of the Lower Triassic Yelang Formation, the host rock of the Sanchahe deposit. Mine assay of sample from the same trench as this sample was 12.2 g gold/ton.

C-15A--Coal seam in the upper part of the Longtan Formation. Sample is from a depth of 108 m in a drill-hole core.

C-16A--Light gray calcareous shale. Core sample from ore zone, 85.0 to 95.7 m depth. Assay from the same horizon was 6.23 g gold/ton.

C-17A--Limestone cut by calcite veinlets at a depth of 22 m in a core.

ANALYTICAL METHODS

The samples were air-dried and ground to pass a 100-mesh (149 µm) sieve. Concentrations of 33 major, minor, and trace elements (Al, Fe, Mg, Ca, Na, K, Ti, P, Mn, Ag, As, Au, Ba, Be, Ce, Co, Cr, Cu, Ga, La, Li, Mo, Nb, Nd, Ni, Pb, Sc, Sr, Th, V, Y, Yb, and Zn) were above limits of detection in at least one sample by inductively coupled, argon-plasma emission spectrometry (ICP). The following elements, with their limits of detection in parts per million in parentheses, were looked for in all samples but not detected in any sample: Bi (10), Cd (2), Eu (2), Ho (2), Sn (10), Ta (40), and U (100). Concentrations of 10 major elements (Si, Al Fe, Mg, Ca, Na, K, Ti, P, and Mn) were also determined by X-ray fluorescence (XRF) with excellent agreement between XRF and ICP results. Concentrations of As, Hg, Sb, Se, Sn, and Tl were determined by atomic absorption spectrophotometry (AAS). Concentrations of total sulfur (TS) and total carbon (TC) were determined using LECO combustion-infrared instrumentation. Carbonate carbon (CC) was determined by coulometric titration of acid-evolved CO_2, and organic carbon (OC) was calculated as the difference between T-C and C-C. 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-$C_{20}H_{42}$), 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 600^{o} C and quantities 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^{o} 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^{o} to 600^{o} C (S_2; mgHC/g rock). CO_2 also is generated by kerogen degradation and is retained during the heating interval from 250^{o} to 390^{o} 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 (Tissot and Welte, 1978). 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).

Carbon stable-isotope ratios were determined by standard techniques (Kaplan and others, 1970; Pratt and Threlkeld, 1984). Powdered samples were oven dried at 40^{o} 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^{o} C, and combusted at 1000^{o} C under oxygen pressure in an 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^{o}-sector, isotope-ratio mass spectrometer. Results are reported in the usual per mil δ-notation relative to the Peedee belemnite marine-carbonate standard (PDB).

Before the samples were ground, a small chip was collected from each sample for organic petrography. The chips were mounted in plastic and polished sections were prepared both parallel and normal to bedding. Vitrinite reflectance measurements were made by incident-light microscopy (Bostick, 1979).

DISCUSSION

The sedimentary-rock hosted disseminated gold deposits in the People's Republic of China have many characteristics that are remarkably similar to those of Carlin-type deposits in western North America. The sizes of the deposits are as yet undetermined, but they contain significant reserves at average grades of 4 to 5 grams per tonne. Gold is less than one micrometer in size and is disseminated in Permian and Triassic silty carbonate black shale host rocks. Gold, arsenic, antimony, mercury, and thallium were introduced with silica and pyrite. Preliminary fluid inclusion data and the presence of hydrothermal illite and kaolinite alteration minerals is similar in both groups of deposits. The geological details of the Chinese deposits are described in Cunningham and others (1988).

Inorganic Geochemistry

Results of geochemical analyses of 20 samples from the Yata, Getang, and Sanchahe deposits are given in Table 1. Summary statistics for all samples are given in Table 2. The Yata deposit samples are C-01 through C-05. Samples C-01B and C-01C are splits of the same sample, and the similarity of analytical results (Table 1) indicates that there was a satisfactory degree of homogeneity of the sample and analytical precision. The greater SiO_2 and lower Al_2O_3 content in sample C-01A in the ore zone agrees with the observed hydrothermally introduced silica in the veins and carbonaceous wallrocks in the vicinity of ore. Element abundances can not be rigorously compared between the mine site and where the host rock was sampled four kilometers away because the latter location was at a lower stratigraphic level, and the TiO_2 and Sn contents probably reflect primary rock variations. Silver was below the detection limit except in one sample of the ore zone. The highest gold values were in the same samples that have the highest concentrations of As, Hg, Sb, Tl, and Se. The concentrations of La and Y generally decrease with increasing degree of mineralization.

The Getang deposit samples are C-06 through C-13 (Table 1). The similarity of results from duplicate samples is shown in samples C-08A and C-08B. The high SiO_2 content and low Al_2O_3, Na_2O, and K_2O contents are in a sample of jasperoid which is best developed above the main ore zone. The highest gold contents are in samples that have the highest concentrations of As, Hg, Sb, and Tl. Sample C-06, from the ore zone, contains 500 ppm Mo. Low-grade coal samples generally contain relatively high concentrations of Co, Cu, Ga, La, Ba, Nb, Nd, Sr, and Th, and unusually high concentrations of Mo and V.

The Sanchahe deposit samples are C-14 through C-17. SiO_2 content generally is higher in samples from rocks that were mineralized. The samples from the ore zone contain the highest concentrations of As, Ba, Ce, Co, Cr, Cu, Ga, La, Nd, Ni, Sr, U, Hg, Sb, Sn, and Tl. The concentrations of a wide variety of elements, some that are mobile in ore-forming solutions and others that are relative refractory, probably results from the superposition of the hydrothermal system on lithologically different strata.

Table 1. Geochemical data for Chinese carbonaceous disseminated gold ores and associated rocks. [Suffix after oxide or element indicates method of analysis; -x, X-ray fluorescence; -i, inductively coupled, argon-plasma emission spectrometry; -a, atomic absorption spectrophotometry; -re, Rock-Eval pyrolysis.]

Sample	%SiO2-x	%Al2O3-x	%Al2O3-i	%Fe2O3-x	%Fe2O3-i	%MgO-x	%MgO-i	%CaO-x
				Yata Deposit				
C-01A	82.10	5.55	5.29	3.50	3.43	.54	.45	1.03
C-01B	66.40	10.00	10.39	5.00	4.86	1.81	1.82	4.22
C-01C	65.80	10.20	10.58	5.00	4.86	1.90	1.99	4.40
C-02A	69.90	6.27	6.61	5.49	5.29	1.89	1.82	3.52
C-03A	51.80	13.70	14.36	11.60	11.58	1.93	1.99	3.52
C-04A	51.60	10.30	10.96	7.77	7.72	3.26	3.32	8.29
C-05A	56.30	17.50	18.51	6.86	6.86	2.39	2.49	3.79
				Getang Deposit				
C-06A	72.30	1.20	1.11	5.90	6.01	.11	.03	9.42
C-07A	52.50	13.40	14.17	6.87	6.58	2.78	2.82	4.92
C-08A	97.80	.73	.57	.14	.19	<.10	.01	<.02
C-08B	97.80	.70	.59	.19	.21	<.10	.01	.04
C-09A	94.50	1.05	.89	2.80	3.00	<.10	.02	<.02
C-10A	71.00	9.48	9.45	6.34	6.15	.35	.30	<.02
C-11A	49.10	23.80	24.56	5.78	5.58	.92	.93	.42
C-12A	5.99	2.38	2.46	.65	.67	.16	.13	.08
C-13A	11.40	2.08	2.08	.83	.84	.15	.13	.62
				Sanchahe Deposit				
C-14A	51.00	12.90	13.79	10.80	10.58	1.46	1.54	6.36
C-15A	15.10	2.41	2.46	1.09	1.06	.36	.33	.60
C-16A	41.00	13.80	14.92	10.30	10.15	2.27	2.32	7.66
C-17A	16.60	.28	.21	.69	.80	.36	.30	46.40

Table 1 (cont.). Geochemical data for Chinese carbonaceous disseminated gold ores and associated rocks.

Sample	%CaO-i	%Na_2O-x	%Na_2O-i	%K_2O-x	%K_2O-i	%TiO_2-x	%TiO_2-i	%P_2O_5-x
				Yata Deposit				
C-01A	.92	<.15	.05	1.26	1.20	.32	.12	.08
C-01B	4.20	.18	.09	2.51	2.52	.54	.18	.13
C-01C	4.34	<.15	.09	2.57	2.52	.55	.17	.14
C-02A	3.50	<.15	.07	1.53	1.56	.35	.12	.11
C-03A	3.64	.18	.13	3.48	3.60	.54	.15	.11
C-04A	8.11	<.15	.09	2.49	2.64	.35	.17	.18
C-05A	3.92	1.19	1.21	2.99	3.12	.72	.53	.15
				Getang Deposit				
C-06A	9.51	<.15	.03	.08	.10	.09	.03	<.05
C-07A	4.90	.40	.39	2.17	2.28	1.46	1.23	.20
C-08A	.03	<.15	.01	<.02	<.06	<.02	.02	<.05
C-08B	.06	<.15	.01	<.02	<.06	<.02	.02	<.05
C-09A	.03	<.15	.01	.08	.08	.08	.08	<.50
C-10A	.03	.24	.22	1.06	1.00	1.30	1.20	.06
C-11A	.43	.81	.73	3.56	3.72	3.32	3.17	.01
C-12A	.10	<.15	.05	.31	.26	.27	.23	<.05
C-13A	.63	<.15	.04	.30	.28	.10	.10	<.05
				Sanchahe Deposit				
C-14A	6.30	.19	.15	2.68	2.76	2.53	1.83	.44
C-15A	.62	<.15	.03	.50	.48	.13	.10	<.05
C-16A	7.69	<.15	.04	3.27	3.60	3.14	1.83	.33
C-17A	46.17	<.15	.01	.04	<.06	<.02	.01	<.05

Table 1 (cont.). Geochemical data for Chinese carbonaceous disseminated gold ores and associated rocks.

Sample	%P205-i	%MnO-x	%MnO-i	ppm Ag-i	ppm As-i	ppm Au-i	ppm Ba-i	ppm Be-i
				Yata Deposit				
C-01A	.05	<.02	.02	<2	2,600	<8	110	<1
C-01B	.14	.06	.07	<2	1,800	<8	190	<1
C-01C	.14	.06	.07	<2	1,700	8	190	<1
C-02A	.09	.09	.10	<2	7,500	10	100	<1
C-03A	.11	.09	.09	4	5,500	12	250	<1
C-04A	.18	.19	.18	<2	3,400	<8	200	<1
C-05A	.14	.05	.06	<2	20	<8	370	2
				Getang Deposit				
C-06A	.01	<.02	.01	<2	2,000	22	16	<1
C-07A	.14	.18	.17	<2	70	<8	110	2
C-08A	.01	<.02	.002	<2	20	<8	22	<1
C-08B	.01	<.02	.003	<2	20	<8	20	<1
C-09A	.01	<.02	.002	<2	520	30	25	<1
C-10A	.05	.04	.05	<2	110	<8	75	<1
C-11A	.09	<.02	.02	<2	290	<8	200	3
C-12A	<.01	<.02	.01	<2	40	<8	70	<1
C-13A	.01	<.02	.003	<2	30	<8	40	1
				Sanchahe Deposit				
C-14A	.30	.18	.18	<2	2,000	<8	220	1
C-15A	.01	<.02	.01	<2	300	<8	60	<1
C-16A	.23	.10	.10	<2	1,600	10	380	<1
C-17A	.02	.12	.15	<2	1,300	<8	10	<1

Table 1 (cont.). Geochemical data for Chinese carbonaceous disseminated gold ores and associated rocks.

Sample	ppm Ce-i	ppm Co-i	ppm Cr-i	ppm Cu-i	ppm Ga-i	ppm La-i	ppm Li-i
				Yata Deposit			
C-01A	20	9	17	28	6	10	11
C-01B	34	14	40	60	13	17	7
C-01C	32	10	33	38	13	16	7
C-02A	23	9	27	31	8	12	7
C-03A	45	37	73	77	18	23	9
C-04A	45	22	54	73	15	24	6
C-05A	62	19	70	44	21	32	46
				Getang Deposit			
C-06A	4	7	34	8	<4	3	17
C-07A	190	14	66	29	25	94	22
C-08A	<4	<1	5	<1	<4	2	13
C-08B	<4	<1	4	<1	<4	2	14
C-09A	7	2	25	10	<4	4	15
C-10A	90	15	80	53	16	49	12
C-11A	190	33	240	60	34	100	93
C-12A	30	4	160	7	6	17	5
C-13A	22	2	69	18	5	9	12
				Sanchahe Deposit			
C-14A	90	38	100	70	26	42	4
C-15A	25	1	7	6	4	10	<2
C-16A	130	48	120	150	24	64	4
C-17A	<4	2	<1	4	<4	<2	<2

Table 1 (cont). Geochemical data for Chinese carbonaceous disseminated gold ores and associated rocks.

Sample	ppm Mo-i	ppm Nb-i	ppm Nd-i	ppm Ni-i	ppm Pb-i	ppm Sc-i	ppm Sr-i
			Yata Deposit				
C-01A	<2	<4	8	23	8	4	13
C-01B	<2	<4	15	39	13	11	190
C-01C	<2	<4	15	31	9	12	180
C-02A	<2	<4	9	22	14	9	130
C-03A	<2	<4	19	73	26	18	270
C-04A	<2	<4	21	37	28	18	450
C-05A	<2	6	28	43	19	19	220
			Getang Deposit				
C-06A	500	<4	<4	24	<4	<2	58
C-07A	4	12	84	32	17	8	220
C-08A	7	<4	<4	3	<4	<2	42
C-08B	7	<4	<4	<2	<4	<2	43
C-09A	7	<4	<4	14	5	<2	57
C-10A	6	29	45	28	8	8	88
C-11A	20	81	92	59	20	26	210
C-12A	150	6	14	44	4	3	79
C-13A	110	8	17	57	5	<2	250
			Sanchahe Deposit				
C-14A	<2	5	48	100	5	20	740
C-15A	<2	<4	14	4	10	3	72
C-16A	2	6	66	89	33	14	1,600
C-17A	<2	<4	4	2	<4	<2	670

Table 1 (cont.). Geochemical data for Chinese carbonaceous disseminated gold ores and associated rocks.

Sample	ppm Th-i	ppm V-i	ppm Y-i	ppm Yb-i	ppm Zn-i	ppm As-a	ppm Hg-a	ppm Sb-a
				Yata Deposit				
C-01A	<4	36	5	<1	42	2,600	13	48
C-01B	12	63	10	<1	110	1,800	9	17
C-01C	6	63	9	<1	88	1,700	8	18
C-02A	<4	37	7	<1	59	7,500	9	200
C-03A	7	96	10	<1	120	5,500	20	81
C-04A	7	87	20	2	95	3,400	4	33
C-05A	10	140	15	2	100	9	0	1
				Getang Deposit				
C-06A	<4	22	5	<1	28	2,000	62	680
C-07A	10	78	17	2	140	93	3	83
C-08A	<4	12	<2	<1	2	7	0	6
C-08B	<4	13	<2	<1	<2	10	0	6
C-09A	<4	42	<2	<1	25	520	17	260
C-10A	6	110	14	2	12	59	2	65
C-11A	18	300	39	4	46	320	7	18
C-12A	<4	430	32	3	17	36	2	17
C-13A	<4	290	49	6	46	20	16	3
				Sanchahe Deposit				
C-14A	150	190	22	2	93	2,000	8	21
C-15A	5	14	16	2	7	260	3	5
C-16A	6	200	11	<1	130	1,600	30	31
C-17A	<4	4	4	<1	3	1,300	34	59

Table 1 (cont.). Geochemical data for Chimese carbonaceous disseminated gold ores and associated rocks.

Sample	ppm Se-a	ppm Sn-a	ppm Tl-a	LOI 900 %	TOC-re	H-index	O-index	δ ^{13}C
				Yata Deposit				
C-01A	<2.0	.5	.7	3.57	--	--	--	--
C-01B	<2.0	.8	1.3	6.98	--	--	--	--
C-01C	<1.0	.6	1.3	7.71	.44	4	115	--
C-02A	<20	.5	.5	8.49	--	--	--	--
C-03A	<5.0	.5	2.7	11.00	1.28	17	16	-27.5
C-04A	<2.0	.7	1.3	14.30	.99	1	25	-27.5
C-05A	.4	2.0	.9	7.90	.47	29	29	--
				Getang Deposit				
C-06A	10	.6	160	6.31	--	--	--	--
C-07A	1.7	2.8	2.3	13.70	--	--	--	--
C-08A	.4	.5	.04	.43	--	--	--	--
C-08B	.2	.5	.02	.39	--	--	--	--
C-09A	1.8	1.1	6.4	.56	--	--	--	--
C-10A	1.5	1.7	1.3	9.52	--	--	--	--
C-11A	3.0	4.0	5.5	11.90	1.94	3	4	-22.3
C-12A	18	.5	.1	89.90	62.2	0	20	-22.1
C-13A	13	.5	.4	84.00	43.2	10	0	-22.2
				Sanchahe Deposit				
C-14A	<2.0	1.6	2.2	9.67	6.96	39	9	-23.6
C-15A	2.3	.5	.0	79.20	.74	4	85	--
C-16A	2.4	3.1	2.7	14.40	1.37	2	28	-23.9
C-17A	1.0	.7	.4	35.60	.41	12	75	--

Table 2. Summary statistics for analyses of sedimentary-rock-hosted, carbonaceous, disseminated gold ores and related rocks from the Yata, Getang, and Sanchahe deposits, southern China. [N is the number of observations out of a total of 20 samples that contained concentrations of a particular element or oxide greater than the lower limit of detection. Suffix after oxide or element indicates method of analysis; -x, X-ray fluorescence; -i, inductively coupled plasma spectrometry; a, atomic absorption spectrophotometry.]

Element or Oxide	Minimum	Maximum	Mean	Standard Deviation	N
% SiO_2-x	6.0	97.8	60.0	27.7	20
% Al_2O_3-x	0.28	23.8	7.89	6.66	20
% Al_2O_3-i	0.20	24	8.2	7.0	20
% Fe_2O_3-x	0.14	11.6	4.88	3.61	20
% Fe_2O_3-i	0.19	11	4.8	3.5	20
% MgO-x	<0.10	3.26	1.14	1.05	17
% MgO-i	0.13	3.3	1.1	1.1	20
% CaO-x	<0.02	46.4	5.28	10.1	17
% CaO-i	0.028	46.	5.3	10	20
% Na_2O-x	<0.15	1.19	--	--	7
% Na_2O-i	0.009	1.2	0.17	0.30	20
% K_2O-x	<0.02	3.56	1.55	1.32	18
% K_2O-i	<0.06	3.7	1.6	1.38	17
% TiO_2-x	<0.02	3.32	0.793	1.04	17
% TiO_2-i	0.013	3.2	0.57	0.85	20
% P_2O_5-x	<0.05	0.500	0.140	0.135	12
% P_2O_5-i	<0.011	0.3	0.088	0.084	19
% MnO-x	<0.02	0.190	--	--	11
% MnO-i	0.002	0.18	0.065	0.064	20
ppm Ag-i	<2	4	--	--	1
ppm As-i	20	7500	1500	2000	20
ppm As-a	7.3	7500	1500	2000	20
ppm Au-i	<8	30	--	--	6
ppm Ba-i	10	380	130	110	20
ppm Be-i	<1	3	--	--	5
ppm Ce-i	<4	190	53	58	17
ppm Co-i	<1	48	14	14	18
ppm Cr-i	<1	240	61	59	19
ppm Cu-i	<1	150	38	37	18
ppm Ga-i	<4	34	13	9	16
ppm Hg-a	0.13	63	12	15	20
ppm La-i	<2	100	27	27	19
ppm Li-i	<2	93	15	21	18
ppm Mo-i	<2	500	--	--	10
ppm Nb-i	<4	81	--	--	8
ppm Nd-i	<4	92	26	27	16
ppm Ni-i	<2	100	36	28	19
ppm Pb-i	<4	33	12	9	16
ppm Sb-a	1.2	680	83	156	20
ppm Sc-i	<2	26	9.3	7.6	20
ppm Se-a	<2	20	--	--	13
ppm Sn-a	<0.5	4	--	--	12
ppm Sr-i	13	1600	280	370	20
ppm Th-i	<4	150	--	--	11
ppm Tl-a	0.04	160	10	35	20
ppm V-i	4	430	110	120	20
ppm Y-i	<2	49	15	13	17
ppm Yb-i	<1	6	--	--	10
ppm Zn-i	<2	140	58	47	19

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Rock-Eval Pyrolysis

Results of Rock-Eval hydrocarbon yield, expressed as HI, for selected samples that had relatively high total organic carbon (TOC) values are given in Table 1. Unfortunately, most samples have been highly altered and have very low hydrocarbon yields even though TOC values were as high as 62%.

Carbon Isotope Ratios

Results of stable-carbon isotope analyses of organic carbon in samples from the Yata, Getang, and Sanchahe deposits (Table 1) are plotted in Figure 3. Also shown in Figure 3 are the results of analyses of samples of Carlin-type disseminated gold deposits from Alligator Ridge, Preble, Jerritt Canyon, Carlin, Cortez, Gold Acres, Horse Canyon, north-central Nevada (Dean and Pratt, 1987; Dean and others, 1987), 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 $\delta^{13}C$ from both the Chinese and Nevada deposits are either isotopically light (between -28 to -32 $^{o}/oo$) or isotopically heavy (greater than about -24$^{o}/oo$). The heaviest values are at least 2.0 $^{o}/oo$ less negative than the heaviest values from Maynard's (1981) Appalachian basin samples, and there is about a 4$^{o}/oo$ gap between the two groups. Dean and Pratt (1987) concluded that the differences in the two groups Carlin-type Nevada samples could not be explained by differences in age, degree of heating, or degree of oxidation.

Samples of silty carbonates from the Xinyuan Formation at the Yata Deposit (C-03 and C-04) have identical values of $\delta^{13}C$ (-27.5$^{o}/oo$) even though sample C-04 is further from the center of the ore body than sample C-03. Samples C-11, C-12, and C-13 are from coal beds in the vicinity of the Getang deposit. There are no significant variations between samples (-22.1 to -22.3 $^{o}/oo$) even though the coal beds were sampled from adjacent to the ore (C-11) and from two kilometers away (C-13). Samples C-14 and C-16 are from silicified limestone and shale in the ore zone of the Sanchahe deposit. The respective analytical values of $\delta^{13}C$ (-23.6 and -23.9$^{o}/oo$) may reflect slight differences in the initial carbon isotopic compositions of limestone and shale.

The carbon isotopic values are similar in samples from within each deposit, regardless of the proximity to ore, but differ significantly between deposits. Values of $\delta^{13}C$ become progressively heavier (^{13}C enriched) as the Precambrian craton is approached, i.e. from Yata to Sanchahe to Getang. Much of the host Xinyuan Formation at Yata consists of turbidites deposited on the continental slope, whereas the shales and limestones of the Sanchahe deposit were deposited in reefs and lagoons, and the coal beds at the Getang deposit formed in swampy coastal environments (Figure 2). These relationships to depositional settings suggest that there is a progressive ^{13}C enrichment as the terrestrial component of the host rocks increases. These results are in accord with the observations of Arthur and others (1985) and Dean and others (1986) that terrestrial organic carbon in rocks older than Miocene is enriched in ^{13}C relative to marine organic carbon in rocks of the same age. This is the opposite trend of modern terrestrial organic carbon which is isotopically light (^{13}C depleted) relative to modern marine organic carbon. It would appear, therefore, that carbon isotopic differences for the Chinese deposits,

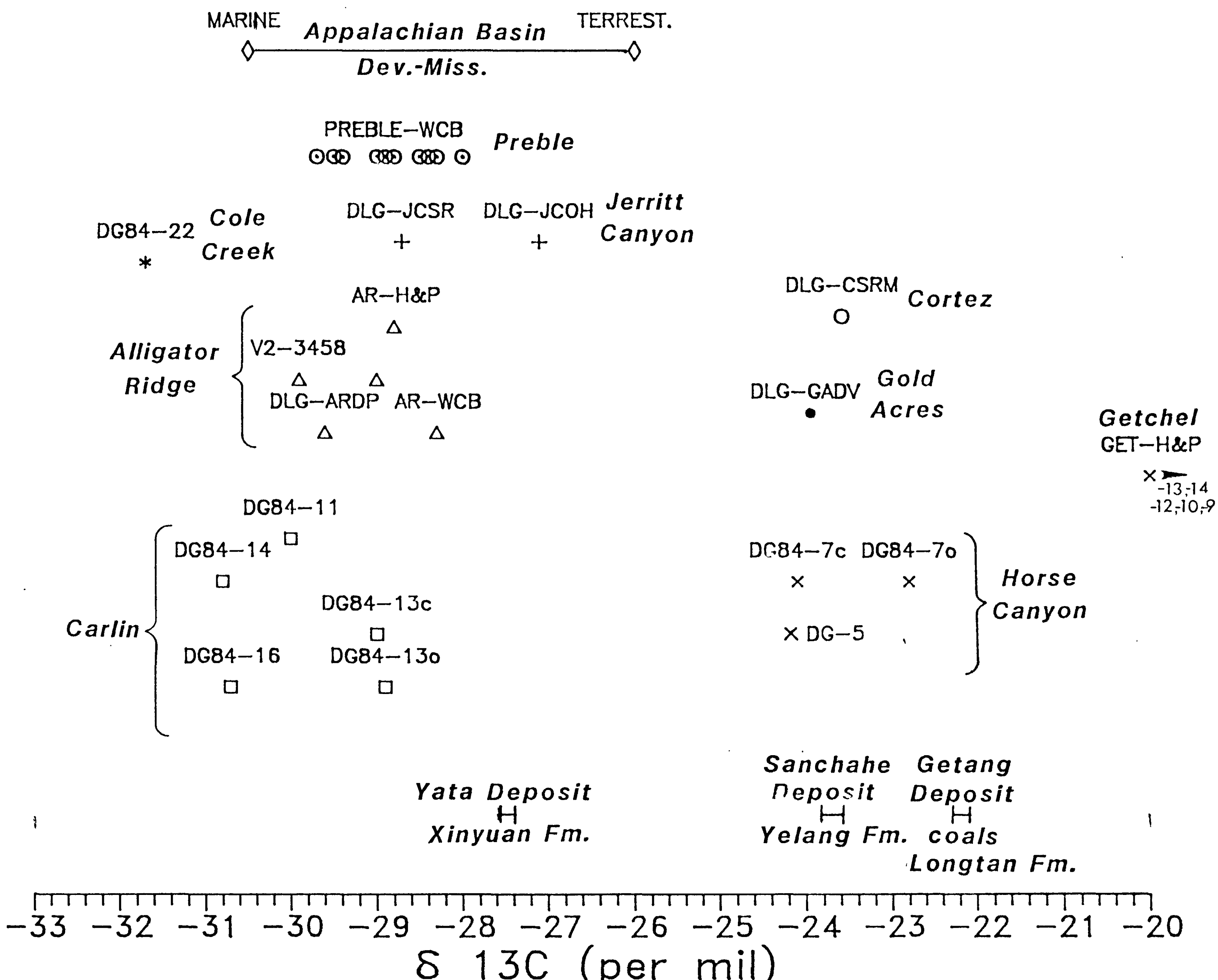

Figure 3. Values of $\delta^{13}C$ for organic matter in samples of Chinese disseminated gold ores and related rocks, and Carlin-type ores and related rocks from Nevada (Dean and others, 1987). Range of values for organic matter in Devonian-Mississippian black shales from the Appalachian basin (Maynard, 1981) are shown for comparison.

as well as those documented for Carlin-type deposits of Nevada (Dean and Pratt, 1987), are due to differences in the sources of the organic matter.

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Table 3 is a summary of vitrinite reflectance measurements expressed as the actual measured median reflectance (%Rf) and vitrinite reflectance equivalent (VRE) which is an estimate of the organic maturation of the sample on a scale of 0.0 to about 5.0.

The Yata deposit has a VRE maturation level of 3.8 and sample C-05 4 km from the deposit has a VRE of 4.3. These levels are equivalent to maturation at the anthracite-metaanthracite boundary in coal. The sparse organic matter and difficulty of locating vitrinite in polished sections precludes attaching any significance to the differences between VRE values at the deposit and that of the single sample 4 km from the deposit except that very local heating in the vicinity of the deposit appears unlikely.

The Getang deposit has essentially the same maturation level, as judged by values of VRE, as the Yata deposit, and the single sample 2 km from the deposit has the same level. Without additional samples from greater distances from the Yata and Getang deposits it is not possible to determine if the deposits formed at geothermally local hot spots or simply deep in a sedimentary basin. Also, it is not possible to determine if ore formation occurred before, during, or after maximum heating of the rocks.

The Sanchahe deposit, with a VRE of 2.8, has significantly lower organic maturation than the other two deposits. However, the difference in maximum lithotemperature attributed to a VRE of about 4.0 for the Yata and Getang deposits and 2.8 for the Sanchahe deposit amounts to only about 30^{o} C.

There are two schools of thought on the relation between thermal matural levels and actual maximum lithotemperatures. One school ascribes considerable significance to the duration of maximum temperature, and the other holds that changes in organic matter resulting from elevated tempeatures are completed in a few thousand years. The latter view is the simplest to calibrate and apply. However, calibrations of vitrinite reflectance with temperature by different authors according to this latter view give maximum temperatures that range from 220 to 365^{o} C for the Yata and Getang deposits , and from 195 to 325^{o} for the Sanchahe deposit.

The view that heating duration is significant can only be applied as hypothetical cases. For example, brief heating such as by a pulse of hot mineralizing fluids, might result in temperatures of about 320^{o} C for the Yata and Getang deposits and 290^{o} C for the Sanchahe deposit. Prolonged heating such as that accompanying deep burial and (or) high regional thermal gradients could account for the measured maturation levels of only 240^{o} C at the Yata and Getang deposits and about 200^{o} C at the Sanchahe deposit.

Because there is no good evidence of highly localized heating at any of the three deposits, it appears that burial heating over millions of years probably occurred yielding temperatures of about 270^{o} C at Yata and Getang and about 240^{o} C at Sanchahe. Such temperatures could be attributed to burial at 5.5 to 6.2 km in a normal thermal gradient of about 40 degrees/km. At a slightly elevated thermal gradient of about 60 degrees/km burial depths of only 3.7 to 4.2 km would be required. All of these burial depths are deep for stable platforms but are common for geosynclinal accumulations and most sedimentary basins.

Table 3. Summary of vitrinite reflectance measurements of Chinese gold ores and associated rocks expressed as actual measured median reflectance (%Rf) and vitrinite reflectance equivalent (VRE). [n= indicates number of observations.]

Sample	%Rf	VRE	Lithology	Comments
			Yata Deposit	
C-01B	3.2?	--	Carbonaceous shale	Very sparce; n=5; no reliable VRE
C-02A	3.8	3.8	Carbonaceous shale	Good; n=62
C-03A	4.0?	4.0?	Carbonaceous shale	Bad; n=17; probably organic ground mass
C-04A	3.7	3.7	Carbonaceous shale	Fair
			4 km from Yata Deposit	
C-056A	4.3	4.2	Carbonaceous shale and carbonate	n=38; very fine material with considerable relief
			Getang Deposit	
C-06A	3.5	3.5	Brecciated shale	Some mosaic material included
C-07A	4.0	3.9	Carbonaceous shale	Good
C-08A	4.0?	4.0?	Silicified limestone	Sparce; n=6; probably some inertinite
C-09A	--	--	Silicified limestone	No visible organic matter
C-10A	4.0	4.0	Coaly shale	Good; n=67
C-11A	4.0	4.0	Carbonaceous shale	n=51
C-12A	3.28	--	Coal	Whole rock
	3.23	3.24		Grains
	3.27	--		Grains
	3.2	--		Grains
			2km from Getang Deposit	
C-13A	3.9	3.8	Coal	n=300; grains
	3.7	--		Whole rock
			Sanchahe Deposit	
C-14A	2.6?	2.6?	Silicified limestone	Sparce; n=9
C-15A	2.9	2.8	Coal	Whole rock
C-16A	3.0	3.0	Calcareous shale	Good but some macrinite possibly included
C-17A	--	--	Limestone	No visible organic matter

REFERENCES CITED

Arthur, M. A., Dean, W. E., and Claypool, G. E., 1985, Anomalous ^{13}C enrichment in modern marine organic matter: Nature, v. 315, p. 216-218,

Baedecker, P. A., Ed., 1987, Geochemical Methods of Analysis: U.S. Geological Survey Bulletin 1770, 129p.

Bostick, N. H., 1979, Microscope measurement of the level of catagenesis of solid organic matter in sedimentary rocks to aid exploration for petroleum and to determine formal burial temperatures--a review, in Scholle, P. A., and Schluger, P. R., eds., Aspects of Diagenesis: Tulsa, Oklahoma, Society of Economic Paleontologists and Mineralogists Special Publication 26, p. 17-43.

Cunningham, C. G, Ashley, R. P., Chou, I-M., Huang, Z., Wan, C., and Li, W., 1988, The newly discovered sedimentary-rock hosted disseminated gold deposits in the People's Republic of China: U.S. Geological Survey Open-File Report 88-220, 14p.

Dean, W. E., and Pratt, L. M., 1987, Pyrolysis, stable-isotope, and major- and trace-element analyses of Carlin-type Gold Deposits, Northcentral Nevada, in Vassiliou, A. H., Hausen, and Carbon, D. J. T., eds., Process Mineralogy VII: Applications to Mineral Beneficiation Technology and Mineral Exploration, with Special Empahasis on Disseminated Carbonaceous Gold Ores: Warrendale, Pennsylvania, The Metallurgical Society, p. 101-121.

Dean, W. E., Arthur, M. A., and Claypool, G. E., 1986, Depletion of ^{13}C in Cretaceous marine organic matter: Source, diagenetic, or environmental signal?: Marine Geology, v. 70, p. 119-157.

Dean, W. E., Pratt, L. M., Briggs, P. H., Daws, T. A., Engleman, E. E., Jackson, L., Layman, L. R., Ryder, J. L., Stone, C. L., Threlkeld, C. N., and Vuletich, A. K., 1987, Data on the geochemistry of Carlin-type disseminated gold deposits and associated rocks, northcentral Nevada: U.S. Geological Survey Open-File Report 87-446, 19 p.

Espitalie, J., LaPorte, J. L., Madec, M., Marquis, F., Leplat, P., Paulet, J., and Boutefeu, A., 1977, Methode rapide de caracterisation des roches meres de leur potential petrolier et de leur degre d'evolution: Revue de l'Institue Francais du Petrole, v. 32, p. 23-42.

Kaplan, I. R., Smith J. W., and Ruth, E., 1970, Carbon and sulfur concentration and isotopic composition in Apollo 11 lunar samples: Geochimica et Cosmochimica Acta, Suppl. 2, p. 1317-1329.

Maynard, J. B., 1981, Carbon isotopes as indicators of dispersal patterns in Devonian-Mississippian shalkes of the Appalachian Basin: Geology, v.9, p. 262-265.

Peters, K. E., 1986, Guidelines for evaluating petroleum source rock using programmed pyrolysis: American Association of Petroleum Geologists Bulletin, v. 70, p. 318-329.

Pratt, L. M., and Threlkeld, C. N., 1984, Stratigraphic significance of $^{13}C/^{12}C$ ratios in mid-Cretaceous rocks of the western interior, U.S.A., in Stott, D. F., and Glass, D. J., eds., The Mesozoic of Middle North America: Canadian Society of Petroleum Geology Memoir 9, p. 305-312.

Tissot, B. P., and Welte, D. H., 1978, Petroleum Formation and Occurrence: New York, Springer-Verlag, 699 p.