. 541

GEOLOGICAL SURVEY CIRCULAR 541

Gold-bearing Sedimentary Rocks In Northwest Wyoming— A Preliminary Report

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Washington 1967

United States Department of the Interior
STEWART L. UDALL, *Secretary*

Geological Survey
William T. Pecora, *Director*

First and second printing 1967

Free on application to the U.S. Geological Survey, Washington, D.C. 20242

CONTENTS

ILLUSTRATIONS

TABLES

Gold-bearing Sedimentary Rocks in Northwest Wyoming—A Preliminary Report[1]

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ABSTRACT

Thick sequences of gold-bearing quartzite conglomerate occur in latest Cretaceous and Tertiary formations and in Quaternary gravels derived from them in northwest Wyoming. Analyses of about 1,200 samples (by a new cyanide-atomic absorption method) and 750 panned concentrates representing 53 localities show the following averages in parts per billion and cents per cubic yard: Harebell Formation (latest Cretaceous), 65 (11 cents); Pinyon Conglomerate (Paleocene), 86 (14 cents); Fort Union Formation (Paleocene), 35 (6 cents); conglomerate of earliest(?) Eocene age, 94 (14 cents); Wind River Formation (early Eocene), 222 (35 cents); Pass Peak Formation of Eardley and others (middle(?) Eocene), 47 (8 cents); Miocene(?) conglomerate, 65 (11 cents); Quaternary deposits, 103 (16 cents). These values are for the bulk rock although the gold is largely confined to sandstone layers and the sandy matrix of the conglomerates, which contain various proportions of pebbles and cobbles. The conglomerates were derived chiefly from Precambrian and possibly Paleozoic quartzite in a now-buried uplift northwest of the Teton Range. Although the grade is low, the volume, 50 cubic miles or more, is so large as to constitute a resource of enormous proportions. The presence of above-average grades in some localities suggests that local concentrations may exist and makes the conglomerates and their derivatives attractive for additional prospecting.

RESULTS

This report presents a summary of analyses (tables 1 to 9) of the first 1,200 of 6,000 samples collected from a sequence of gold-bearing sedimentary rocks in northwest Wyoming and adjacent areas. The following conclusions and procedures, potentially useful to modern prospectors, are based on a preliminary study of the field and laboratory data related to these samples: (1) Gold occurs in all areas of Cretaceous and Tertiary quartzite-bearing conglomerate that have been sampled in northwest Wyoming, (2) the volume of low grade gold-bearing strata is so vast (50 cu mi or more) that development of new mining and recovery methods designed for low-cost handling of huge quantities of relatively poorly consolidated material may eventually be justified, (3) most of the gold was not derived from adjacent mountains but came from Precambrian and possibly Paleozoic quartzite in a now-buried uplift northwest of the Teton Range, (4) to analyze for gold in such low concentrations, a method combining cyanide extraction and atomic absorption was found most reliable, and (5) analyses of 754 panned concentrates demonstrate some of the problems of recovering gold by mechanical and chemical methods and of evaluating various types of analytical data.

We believe that there are genuine, even though small, variations in amounts of gold from one place to another and that these are not necessarily random but may be clues to the locations of large-tonnage deposits of possible economic significance. Because of the current interest in gold, evidence supporting our conclusions is given in this preliminary report in advance of completion of the final study. Sampling has not yet been done in sufficient detail to locate any areas of relatively high gold content, but we feel that the data shown in table 1 indicate the desirability of further intensive prospecting.

The results reported herein are based mainly on determinations of the gold content of small samples. A joint investigation with the U.S. Bureau of Mines is planned to develop methods for measuring the gold content of much larger samples and for technological appraisal of the deposits.

GEOLOGIC DISTRIBUTION OF GOLD

Placer gold has been known in northwest Wyoming for more than 100 years, but it is in such small flakes (max diam about 0.3 mm, and thickness less than 0.01 mm) that conventional recovery methods have not been commercially successful.

Table 1 summarizes data on the Cretaceous and younger sequences sampled for this study and shows their average gold content. More detailed descriptions of these gold-bearing strata—Harebell Formation and Pinyon Conglomerate (Love, 1956; 1956a), Fort Union Formation (Pierce, 1966; Hewett, 1914; 1926), Wind River Formation (Rohrer, 1967), Pass Peak Formation of Eardley and others (Eardley and others, 1944; Dorr, 1956), and Quaternary deposits (Maguire, 1899; Love, 1956a; Love and Taylor, 1961)—are found in the literature cited. The Miocene(?) conglomerates have not been described in publication

[1]Prepared with the cooperation of the Geological Survey of Wyoming and the Department of Geology, University of Wyoming.

Table 1.—Gold content of Cretaceous and Tertiary rocks and Quaternary deposits

Age	Formation	Lithology	No. of samples	No. of localities	Au content in ppb; dollars per cubic yard[1/] in parentheses: Average of all samples	Au content in ppb; dollars per cubic yard[1/] in parentheses: Maximum in single sample
Quaternary-------	----------------------	Gravel, sand, silt, and clay--	178	14	103 ($0.16)	2,000 ($3.20)
Miocene(?)-------	----------------------	Quartzite conglomerate and sandstone with tuff matrix.	21	1	65 (.11)	290 (.46)
Middle(?) Eocene-	Pass Peak Formation of Eardley and others (1944).	Quartzite conglomerate, sandstone, and siltstone.	25	1	47 (.08)	250 (.40)
Early Eocene-----	Wind River Formation--	Sandstone and quartzite conglomerate.	40	3	222 (.35)	2,000 (3.20)
Earliest(?) Eocene	----------------------	----do------------------------	26	1	94 (.14)	400 (.64)
Paleocene--------	Pinyon Conglomerate---	Quartzite conglomerate, sandstone, coal, and shale.	652	16	86 (.14)	6,000 (9.60)
Paleocene--------	Fort Union Formation--	Quartzite conglomerate, and sandstone.	14	1	35 (.06)	300 (.48)
Late Cretaceous--	Harebell Formation----	Quartzite conglomerate, sandstone, and siltstone.	145	5	65 (.11)	1,000 (1.60)

[1/] The value of placer deposits is commonly expressed in dollars per cubic yard. To convert to dollars per ton, divide dollars by 1.6. 1 cu yd equals 1.6 tons; 10 ppb equals 1 cent per ton; 1 cent per ton equals 1.6 cents per cu yd.

but are similar to those in the Colter Formation (Love, 1956), 20 miles to the southeast.

Sample localities are shown on figure 1, and many are shown also on figure 2, a generalized geologic map (Love, 1956) that shows distribution of the Harebell Formation and Pinyon Conglomerate, the thickest and most widespread gold-bearing conglomeratic sequences in northwest Wyoming.

HAREBELL FORMATION

The Harebell Formation was deposited during latest Cretaceous time by a river system that flowed southeastward across Jackson Hole and brought quartzite debris from a now-buried source uplift northwest of the Teton Range. The trough line of maximum conglomerate deposition was near localities 10, 11, and 12, along the present course of the Buffalo Fork River. Conglomerates decrease in thickness and abundance to the north and south of that area.

The distribution of gold in various rock types in the Harebell Formation is summarized in table 2. Gold is more abundant in sandstone than in conglomerate. Among conglomerates, gold is most abundant in ferruginous varieties having some round stones larger than 3 inches and in conglomerate having a soft matrix. Ferruginous rocks containing organic debris appear to be particularly favorable hosts for gold. Table 3 gives the maximum, minimum, and average gold content at each of five sample localities, and table 1 shows a combined average. Regional distribution of gold elsewhere in the areas of outcrop (fig. 2) is being investigated.

PINYON CONGLOMERATE

The Pinyon Conglomerate was deposited by rivers that flowed from the quartzite source area eastward and southeastward across Jackson Hole although in courses different from those of the rivers that deposited the Harebell Formation. One river turned northeast and went past the present location of the town of Cody (fig. 1) in the Bighorn Basin. The area of maximum conglomerate deposition was in the vicinity of locality 5 and Gravel Mountain (fig. 2), where more than 5,000 feet of strata, largely conglomerate, was deposited. Farther east and southeast, the conglomerates thin and intertongue with sandstone.

Table 2 shows that the pattern of gold distribution in the Pinyon Conglomerate is similar to that in the Harebell Formation. In both formations gold is most abundant in sandstone. In the Pinyon, however, gold is appreciably more abundant than in the Harebell. Carbonaceous sandstone in the Pinyon has the highest average gold content of any samples.

Table 4 shows that both average and maximum gold content vary considerably from one locality to another. A cluster of localities (32, 33, 34, 36) in the southeast part of Jackson Hole displays moderately high values. Whether these richer localities are parts of linear trends of gold concentration has not yet been determined, for analytical data from the large areas of Pinyon Conglomerate farther north are presently incomplete.

FORT UNION FORMATION

The Fort Union Formation in the Bighorn Basin is an approximate eastern equivalent of the Pinyon Conglomerate plus the overlying sandstone, siltstone, and claystone of Paleocene age. Quartzite conglomerates were sampled in many places and parts of the section but, as yet, analyses are available for only one locality (52, fig. 1; table 5) in the lower 200 feet of a 5,000-foot succession. Table 1 shows that the gold content at this locality is much less than in the Pinyon Conglomerate. Analyses of conglomerates from other areas, however, may alter this preliminary

Table 2.—Data on samples from Harebell Formation and Pinyon Conglomerate

Material	No. of samples analyzed		No. with Au content 100 ppb or greater		Avg Au content in ppb; cents per cu yd in parentheses	
	Harebell	Pinyon	Harebell	Pinyon	Harebell	Pinyon
Roundstones (most are quartzite, but some are schist, granite, etc.)	11	112	0	4	19(3)	26(4)
Conglomerate, some roundstones larger than 3 in	37	175	6	35	52(8)	77(12)
Ferruginous conglomerate, some roundstones larger than 3 in	12	31	4	6	73(12)	60(10)
Conglomerate, roundstones smaller than 3 in	5	16	1	5	45(7)	143(23)
Ferruginous conglomerate, roundstones smaller than 3 in	2	3	0	2	30(5)	103(16)
Conglomerate with tough matrix	23	77	3	12	48(8)	52(8)
Conglomerate with soft matrix	24	127	7	30	70(11)	88(14)
Conglomerate overlying sandstone	5	6	0	1	40(6)	103(16)
Ferruginous conglomerate overlying sandstone	1	0	0	0	30(5)	0 --
Conglomerate under sandstone	4	8	0	4	23(4)	153(24)
Ferruginous conglomerate under sandstone	0	2	0	0	-- --	40(6)
Sandstone overlying conglomerate	10	30	3	9	120(19)	106(17)
Ferruginous sandstone overlying conglomerate	1	2	0	1	60(10)	348(56)
Pebbly sandstone lens	2	4	0	2	40(6)	94(14)
Sandstone lens	12	50	2	11	123(20)	118(19)
Ferruginous sandstone lens	9	22	2	4	45(7)	74(12)
Sandstone lens under conglomerate	5	18	1	5	98(16)	61(10)
Ferruginous sandstone lens under conglomerate	5	--	2	--	114(18)	-- --
Massive sandstone	6	14	1	3	47(8)	55(9)
Sandstone-shale	2	3	1	1	80(13)	100(16)
Ferruginous sandstone-shale	3	2	0	0	57(9)	50(8)
Sandstone with organic content or plant fossils	2	12	0	4	35(6)	430(69)
Ferruginous sandstone with organic content or plant fossils	3	--	3	--	127(20)	-- --
Shale	1	13	1	2	100(16)	42(7)
Limestone	2	11	0	1	20(3)	41(7)
Coal	0	9	0	0	-- --	27(4)
Soil on, or derived from, conglomerate	15	49	1	6	48(8)	36(6)
Stream sediment in area of conglomerate	--	75	--	18	-- --	192(31)
Conglomerate with clayey matrix	--	7	--	3	-- --	344(55)
Silicified wood	--	4	--	0	-- --	19(3)
Summary[1]						
Nonferruginous samples	84	346	16	78	72(12)	104(17)
Ferruginous samples	35	60	11	13	72(12)	77(12)
Conglomerate	56	225	11	48	55(9)	80(13)
Sandstone	55	152	14	39	81(13)	122(20)
Shale	6	18	2	3	72(12)	52(8)
Material containing carbonaceous debris	5	12	3	4	90(14)	430(69)
Limestone	2	11	0	1	20(3)	41(7)
Soil	15	49	1	6	48(8)	36(6)
Roundstones	11	112	0	4	19(3)	26(4)

[1] Some samples are included in more than one category in the preceding detailed list.

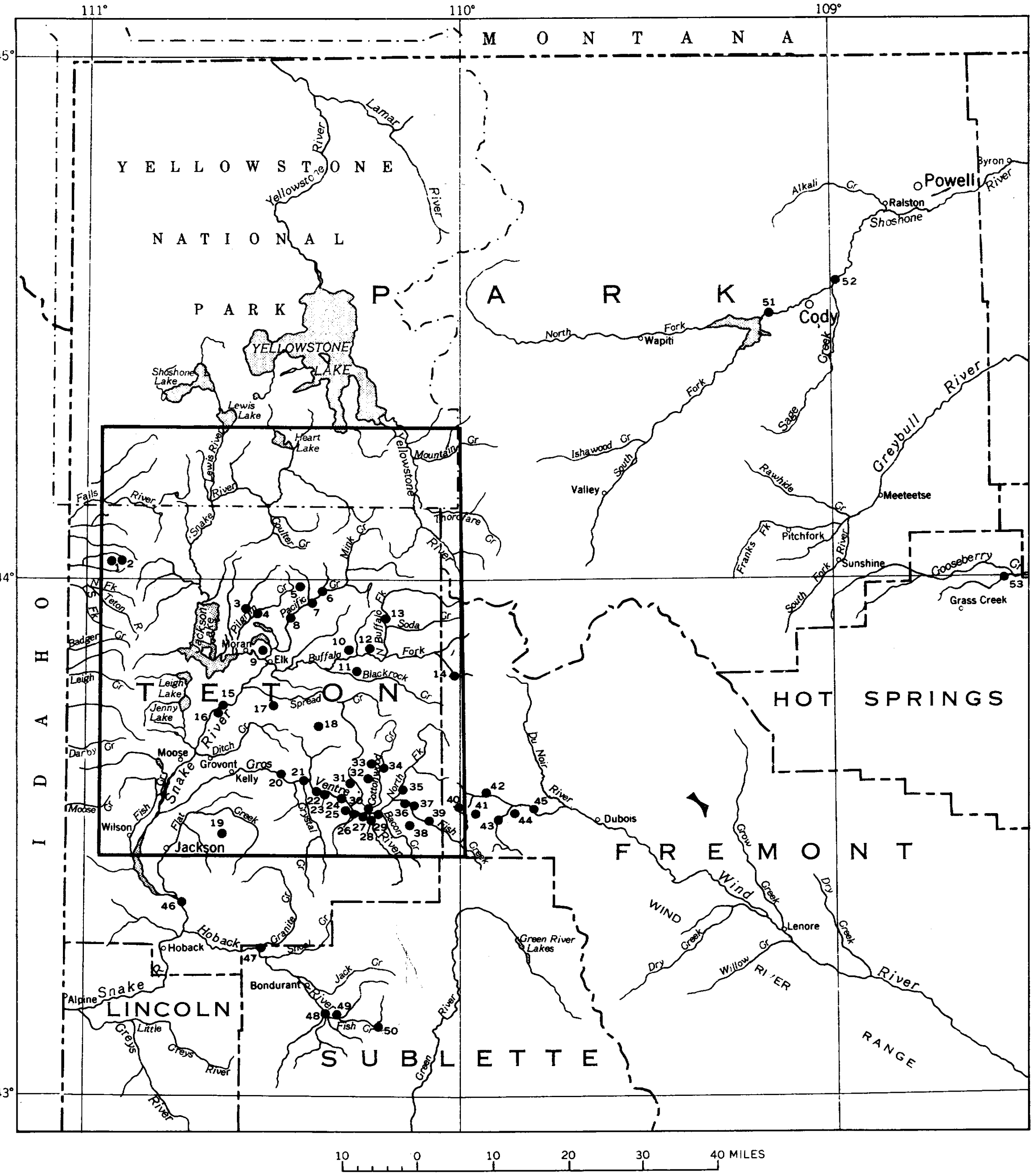

Figure 1.—Northwest Wyoming, showing numbered localities sampled for gold. Heavy line marks boundaries of area included in figure 2.

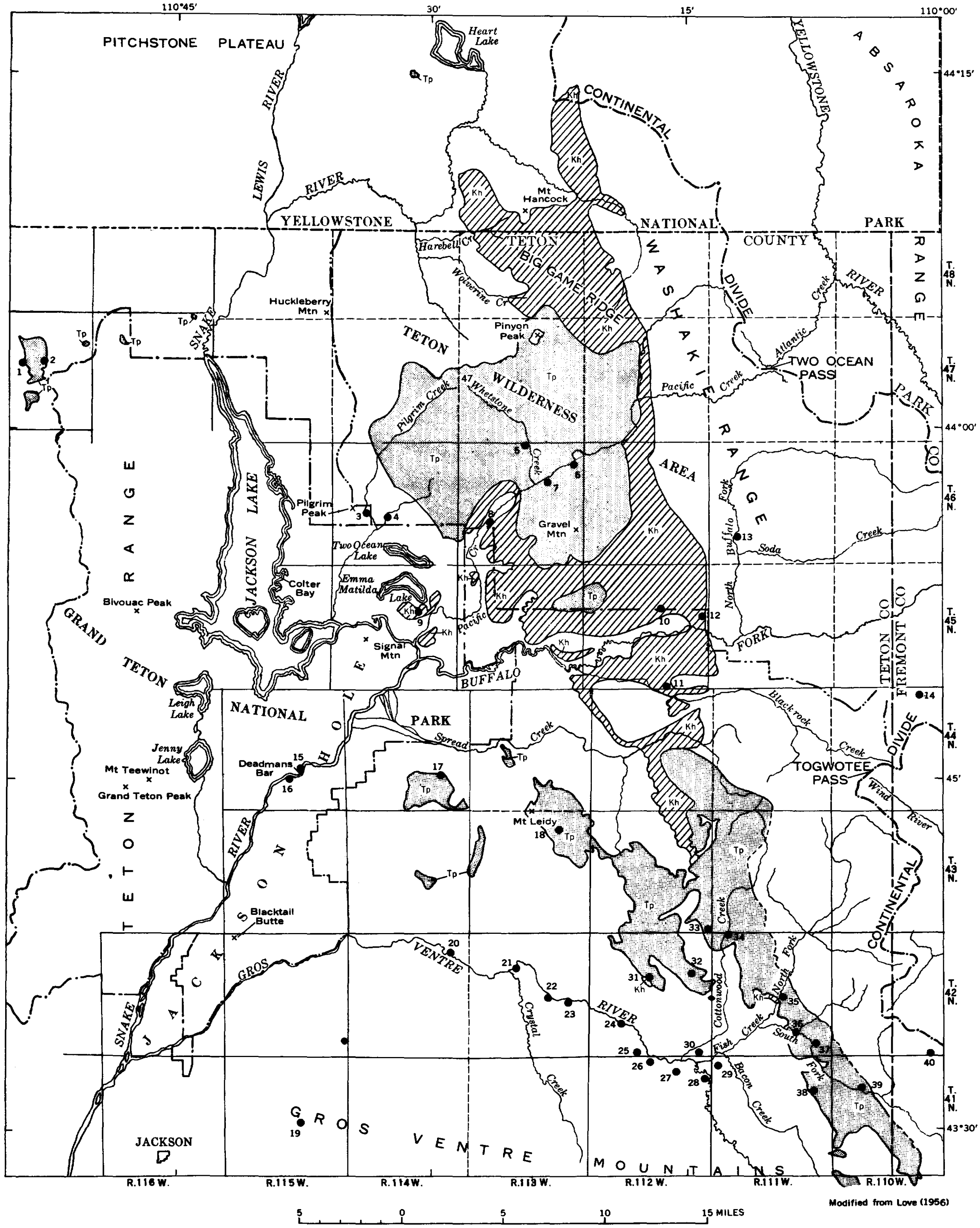

Figure 2.—Part of Jackson Hole area, showing numbered localities sampled for gold and major outcrop areas of Harebell Formation (Kh) and Pinyon Conglomerate (Tp). Boundaries of Grand Teton National Park and Teton Wilderness Area are approximately located. Geology adapted from Love (1956).

observation. The gold almost certainly came from the same source area as that in the Pinyon.

Table 3.—Gold content of sampled localities in Harebell Formation

Locality	No. of samples	Au content (ppb) Range	Average
9	23	<10- 200	31.3
10	39	<10- 200	43.3
11	59	<10-1,000	99.7
12	10	15- 250	70.0
31	14	15- 400	65.2

Table 4.—Gold content of sampled localities in Pinyon Conglomerate

Locality	No. of samples	Au content (ppb) Range	Average
2	13	40- 700	145.4
5	74	<10-2,000	75.4
6	37	<10-6,000	203.0
7	31	<10- 250	52.9
17	33	<10- 80	33.7
18	84	<10- 340	50.4
31	31	<10- 500	73.2
32	103	<10-4,350	112.7
33	26	<10-1,000	116.3
34	39	<10-3,250	151.0
35	45	<10- 200	30.2
1/35S	30	<20- 660	85.0
36	20	35- 500	138.0
37	24	<10- 280	50.8
38	31	<10- 200	27.6
39	31	<10- 450	87.1

1/ Scarp.

CONGLOMERATE OF EARLIEST(?) EOCENE AGE

Several hundred feet of quartzite conglomerate similar to that in the Pinyon and Fort Union but overlying the Fort Union in the Bighorn Basin has been considered to be part of the Willwood Formation of early Eocene age (Hewett, 1926, called it Wasatch but the name was later changed). Recent work by the writers suggests that the Willwood may unconformably overlap this conglomerate, so the conglomerate is herein called earliest(?) Eocene and tentatively set apart from both the Willwood and Fort Union Formations. The quartzite debris may have been derived from the Harebell, Pinyon, and Fort Union Formations, or it might have come directly from the same source area as the older conglomerates. Tables 1 and 5 show that the gold content of samples from one locality (53, fig. 1) is higher than the average for any of the older formations in either the Bighorn Basin or Jackson Hole.

WIND RIVER FORMATION

The Wind River Formation of early Eocene age is present along the Continental Divide (fig. 2) between the Wind River Basin and Jackson Hole and includes several quartzite conglomerates and brown sandstones similar to those in the Pinyon Conglomerate. The Wind River is between 500 and 1,000 feet thick and is especially interesting because the average gold content of samples analyzed to date is more than twice that of any other formation (tables 1 and 5). These rocks lap southward onto the Flathead Sandstone (Cambrian) and the Precambrian crystalline core of the Wind River Range. Analyses of four samples of Flathead Sandstone at two localities (44 and 45, fig. 1; table 6) show 100 to 150 parts per billion (ppb), or 16 to 24 cents per cubic yard, gold. Elsewhere (locs. 14 and 19), the Flathead has only 15 to 25 ppb, or 2½ to 4 cents per cubic yard, gold. These

Table 5.—Gold content of sampled localities of quartzite conglomerate in formations other than Harebell and Pinyon, northwestern Wyoming

Locality	Rock	No. of samples	Au content (ppb) Range	Average
52	Fort Union Formation------------	14	<10- 300	35.4
53	Lowest(?) Eocene conglomerate Bighorn Basin----------------	26	15- 400	94.4
40	Wind River Formation------------	23	<10-2,000	220.0
41	----do--------------------------	3	70- 500	227.0
42	----do--------------------------	14	10-1,250	223.2
	Summary (40, 41, 42)-------	40	<10-2,000	221.8
50	Pass Peak Formation of Eardley and others (1944)---------------	25	<10- 250	46.6
1	Quartzite boulder conglomerate in Miocene(?) pyroclastic sequence----------------------	21	<10- 290	64.8

Table 6.—Gold content of miscellaneous igneous and sedimentary rocks in northwestern Wyoming

Locality	Rock	No. of samples	Au content (ppb) Range	Average
19	Flathead Sandstone--------------	4	20-25	22.5
44, 45	-----------do-------------------	4	100-150	132.5
51	-----------do-------------------	3	15-70	38.3
14	Flathead Sandstone and volcanic conglomerate of Oligocene Wiggins Formation-------------	2	<100	<100
13	Precambrian gneiss and schist; Cambrian Flathead Sandstone; and sediment in streams draining Tertiary volcanic rocks-------------------------	22	<10-100	25.0
19	Precambrian granite-------------	2	15	15.0
51	-----------do-------------------	1	50	--

preliminary data suggest that the Flathead may locally contain significant amounts of gold, probably derived from the Precambrian crystalline rocks of the Wind River Range. Some of this gold may have been reworked into the Wind River Formation. The Flathead Sandstone and adjacent beds of the Wind River Formation on both flanks of this part of the Wind River Range warrant further investigation.

PASS PEAK FORMATION OF EARDLEY AND OTHERS

The Pass Peak Formation of Eardley and others (1944) contains more than 2,000 feet of quartzite conglomerate along the south margin of the Gros Ventre Mountains; the conglomerate facies thins abruptly southward into sandstone. The age is uncertain but is probably middle Eocene. This conglomerate was almost certainly reworked from conglomerates in the Pinyon and Harebell Formations of Jackson Hole before the Gros Ventre Mountains rose to their present height (Dorr, 1956; Love; 1956b, 1960, p. 208-209). About 1,000 feet of section was sampled (loc. 50, fig. 1); the gold content averages somewhat less than that of all the older formations except the Fort Union (tables 1 and 5).

MIOCENE(?) CONGLOMERATE

A greenish-brown very coarse boulder conglomerate about 100 feet thick is in a sequence of pyroclastic rocks that directly overlies the Pinyon Conglomerate on the northwest side of the Teton Range at locality 1 (fig. 2). Many of the boulders are of quartzite, highly rounded, 2 to 3 feet in diameter, and are identical in size, appearance, and composition to those in the Pinyon. The matrix of the younger conglomerate is andesite crystal tuff, and the petrography, nature of matrix igneous material, and general appearance are much like those of the Colter Formation of Miocene age in Jackson Hole 20 miles to the southeast (Love, 1956). The gold content is slightly less than that in the Pinyon Conglomerate (tables 1 and 5).

QUATERNARY DEPOSITS

Maguire (1899) estimated that alluvial gravel along the Snake River downstream from the town of Jackson (fig. 1) contains at least $2 billion worth of gold (at $20.00 per oz). Table 7 presents the gold content of similar Quaternary deposits farther upstream that were derived chiefly from quartzite conglomerate in the Harebell, Pinyon, Pass Peak, and Wind River Formations. Table 1 shows that the average gold content in 178 alluvial samples is higher than that of any parent formation except the Wind River. All types of alluvial debris, ranging from coarse boulder deposits to very fine grained clay, were sampled. The greatest gold concentration is in gravel and coarse sand, but some high values have been found in finer grained sand

Table 7.—Gold content of sampled localities in Quaternary deposits derived chiefly from the Harebell Formation, Pinyon Conglomerate, Wind River Formation, and Pass Peak Formation of Eardley and others (1944)

Locality	No. of samples	Au content (ppb) Range	Average
3	5	<10-1,000	228.0
4	5	<20-2,000	739.0
8	20	<10- 300	66.0
15	14	<10- 300	104.6
16	16	<10- 250	65.0
20	49	<10- 600	44.0
1/20	20	<10-1,200	107.0
21	4	<10-2,000	579.0
23	9	<10- 30	3.3
24	12	<10- 600	88.8
30	8	<10- 40	21.2
45	8	<10- 500	188.7
46	7	25- 100	57.1
49	1	25	25

1/ River bottom.

and silt trapped in sod and at the roots of willow bushes along stream margins.

Alluvial deposits derived largely or entirely from pre-Harebell rocks were sampled in order to determine whether any significant amount of gold came from sources other than conglomerate. Results are given in tables 8 and 9. These data indicate that the Harebell and younger conglomeratic strata are the chief sources of gold in Quaternary deposits.

GEOCHEMICAL PROBLEMS AND PROCEDURES

In order to evaluate the significance of variations in distribution of gold in deposits such as those in northwest Wyoming, an adequate analytical method is necessary for determining chemically the amount of gold, and a satisfactory procedure must be devised to produce mechanical concentrates containing the maximum amount of gold; concentrates are useful not only to cross check analyses of unconcentrated samples but also to provide data on distribution and recovery of very small gold particles.

Related problems are: (1) the large volume of material (50 cu mi or more) to be sampled, (2) terrane so rough that it cannot quickly be explored, and (3) serious sampling difficulties because of the erratic distribution of discrete particles of gold, which is so malleable that it does not break up easily in grinding.

ANALYTICAL METHOD

The analytical method described here was developed as a part of this study in order to secure reliable data in the part-per-billion range on the gold content of the material that is actually analyzed. Details of the procedure and equipment needed are included here because they may be of value to others engaged in similar work. Most of the unconcentrated samples were analyzed by W. L. Campbell and Elizabeth Martinez, using this new method. In Addition, all were analyzed by other, less sensitive methods. The values reported in the tables are based on averages of at least two determinations for almost all samples; some samples were analyzed as many as five times. The other methods used and the analysts (names in parentheses) are: sodium bromate-hydrobromic acid-colorimetric method of Lakin and Nakagawa (1965), using 1- and 5-gram samples (J. C. Antweiler); sodium bromate-hydrobromic acid-atomic absorption procedure, using 2-g samples (Walter Ficklin and Sharon Noble); cyanide-atomic absorption procedure, using 15-g samples (Walter Ficklin, Sharon Noble, Luther Dickson, and J. C. Antweiler); cyanide-colorimetric procedure, using 15-g samples (J. C. Antweiler); and fire assay-atomic absorption procedures, using approximately 15-g (half assay ton) samples (O. L. Parker, C. H. Huffman, Jr., and John Mensik). J. C. Antweiler assumes the responsibility for the values reported.

The new method gave the best results. Recovery of gold was tested by analyzing samples to which a known amount of radioactive Au^{198} had been added and then measuring the radioactivity of the recovered gold; recovery averaged 90 percent. Accuracy was constantly checked by preparing procedural blanks and standards on material similar to that being analyzed and by referring each sample to these blanks and standards for comparison. The true mean at the 90-percent confidence limit for a 20 ppb standard is between 22 and 17 ppb (F. S. Fisher, written commun.). Values at 10 ppb are almost as good, and those at 100 ppb are considerably better.

Table 8.—Gold content of alluvium derived largely or entirely from pre-Harebell rocks

Locality	Material	No. of samples	Au content (ppb) Range	Average
22, 25 26, 27, 28, 29.	Stream sediments, landslide and glacial debris from Paleozoic and Mesozoic rocks in Gros Ventre Mountains	24	<10-50	11.3
43	Stream sediment. Drainage from Precambrian granite of Wind River Mountains and in part from Wind River Formation	2	<10-70	35
47	Glacial debris left by glacier that flowed southward from Gros Ventre Mountains along valley of Granite Creek	2	20-80	50.0
48	River gravel in Hoback River at U.S. 189 southeast of Bondurant	2	<10	<10

Apparatus and reagents

Atomic absorption spectrophotometer. The instrument used in this work was a Perkin-Elmer 303.

Shaker capable of handling 25- by 200-mm screwcap test tubes.

25- by 200-mm screwcap test tubes.

Water bath.

Centrifuge.

Sodium peroxide.

0.25-percent sodium cyanide solution: Dissolve 2.5 g sodium cyanide in 1 liter of water.

1:1 HBr solution containing free Br_2: Add 1 liter of hydrobromic acid and 10 g sodium bromate to 1 liter of water.

Methyl isobutyl ketone (MIBK).

Procedure

1. Roast 15 g of sample 1 hr at 600°C. When cool, add 0.1 g Na_2O_2.
2. Add 30 ml 0.25-percent NaCN solution to 25- by 200-mm screwcap test tube. Heat tube and contents to 85° in a water bath.
3. When the sodium cyanide solution is hot, add the roasted samples containing sodium peroxide. Allow to digest a few minutes in the water bath.
4. Cap the tube and shake for 15 minutes. After shaking, allow the sediment to settle, and siphon or decant the solution into another 25- by 200-mm screwcap test tube.
5. Add 10 ml 1:1 HBr solution containing free bromine to sediment remaining in first test tube. Heat tube and contents to 85° on water bath. Cap and shake 5 minutes. Allow sediment to settle after shaking, and siphon or decant HBr into the same test tube containing the cyanide extract. (CAUTION: Use a hood. Hydrogen cyanide is liberated.)
6. Digest the combined cyanide and bromide solutions on the water bath at 85° for ½ hr. Allow the tube to cool to room temperature.
7. Add 10 ml MIBK and shake for 2 minutes. Centrifuge if necessary to get a sediment-free layer of MIBK. Determine gold content in the MIBK layer by atomizing MIBK in the atomic absorption spectrophotometer, referring to the blanks and standards as described below.

Preparation of blanks and standards

Standard gold cyanide solution: Prepare a stock solution containing 1 mg of gold per ml by dissolving 100 mg of gold with aqua regia and diluting to 100 ml. Prepare a stock cyanide solution containing 100 micrograms of gold per ml by neutralizing 10 ml of the aqua regia solution with sodium hydroxide and diluting to 100 ml with 0.25-percent sodium cyanide solution. Dilute the stock cyanide solution with appropriate volumes of 0.25-percent sodium cyanide solution to obtain daily working solutions containing 1 and 10 micrograms gold per ml.

Barren sample material: Roast 1 hr at 600°C several hundred grams of material known to contain less than a measureable amount of gold but similar in general composition to the samples to be tested.

Procedural blanks and standards: Add 15 g of barren sample material and 0.1 g Na_2O_2 to a series of screwcap test tubes. Prepare a series of blanks and standards containing 0, 10, 20, 50, 100, 500, and 1,000 ppb gold by pipetting 0, 0.1, 0.2, 0.5, and 1.0 ml of the standard containing 1 microgram gold per ml, and 0.5 and 1.0 ml of the standard containing 10 micrograms of gold per ml into the tubes (all the gold added is recovered in 10 ml MIBK; therefore each ml MIBK contains 1/10 of the gold added). Run these blanks and standards through procedure steps 2 to 7 exactly like samples, setting the atomic absorption instrument to obtain a reliable curve that spans the range of gold content of the samples to be analyzed. Determination of gold for each sample by atomic absorption should be preceded and followed by readings of the blank in order to verify instrumental stability. Refer to the standard curve after each 10th sample, and make instrumental adjustments if necessary.

SAMPLING

We wish to emphasize that this report is not intended to present a resource appraisal but rather the preliminary results of geological and geochemical exploration. The objectives are to establish guides to prospecting, to locate areas that may warrant more detailed studies, and to obtain information on the source, areal distribution, and stratigraphic extent of gold. Consequently, the samples collected were small (1 to 2 lb), and preference was commonly given to sampling conglomerate matrix and sandstone lenses because previous analytical work showed that such samples are more likely to have concentrations of gold than are round stones. Round stones were included in samples of conglomerate but commonly were not in proportion to their abundance because of their size and the limitations on the weight of sample that could be collected. It is readily apparent that removal of pebbles and larger round stones from conglomerates will increase the gold content of the matrix material significantly.

A statistical analysis by A. T. Miesch (written commun., 1966) of grade and particle size shows that even with a definite sampling pattern, sampling problems are certain to occur. Experimental data obtained in the present study confirm the statistics and show that the sampling error is large. The average mass of gold particles recovered by washing in a gold pan is about 8 micrograms; the average grade found so far at most localities is between 50 and 100 ppb. To obtain reliable evaluation data at this level of particle size and concentration, very large samples (several hundred pounds) should be taken because most 15-g samples will not contain even one gold particle. Although the particles are very small (more than 1,000 are required to make 1 cent's worth of gold), they are not evenly distributed, and wide deviations in analytical results are therefore inevitable.

It is important to note that one or a few samples with relatively high gold content can change significantly the average grade at a locality and that these high values cannot be excluded because such scatter in analyses is typical of economic deposits. For example, in a study of gold ore from the Witwatersrand in South Africa, the U.S. Bureau of Mines found that one-half of the gold was in fewer than 10 percent of 495 samples; and in ore from the Homestake mine in South Dakota, one-half of the gold was in 3 percent of 219 samples (George S. Koch, Jr., written commun., 1966).

A final word of caution concerns gold analyses in all tables. The figures presented do not necessarily provide a basis for quantitative comparisons of gold values between one area and another because different sampling patterns rather than sampling problems or actual differences in gold content may account for some of the variations.

PANNED CONCENTRATES—THEIR PROBLEMS AND CONTRIBUTIONS

In an attempt to solve the difficult problem of determining reliably the gold content of rocks containing very small amounts of gold, extensive experiments were made to preconcentrate large samples and then to analyze the concentrates.

As a test of the effectiveness of a simple concentration method in obtaining representative 15-g samples for analysis, 754 field samples, for which bulk analyses were available, were concentrated by hand panning with a gold pan, and the concentrates were analyzed. This procedure should facilitate determination of the gold content of several hundred grams of sample but, like the bulk sample analyses, is subject to error that may be very large. The panned concentrates were analyzed for gold using a sodium bromate-hydrobromic acid-atomic absorption procedure that is quite satisfactory for small samples with high gold content. Panning was done by J. G. Frisken, W. H. Raymond, F. S. Fisher, and J. C. Antweiler, and analyses were made under the direction of J. C. Negri by Elizabeth Martinez, S. McDanal, H. King, B. Hansen, A. Toevs, A. Meier, T. A. Roemer, C. Cole, and R. Miller.

Averages of the gold content in concentrates from each locality are given in table 9. The field samples and the concentrates obtained from them were weighed, and the percentage of gold recovered in the concentrates, shown in the last column of table 9, was obtained by computation from the gold content of the bulk samples. A few analyses were made of the material that floats and remains in suspension when the sample is first wet with water, and some analyses were made of the material washed out of the pan during the panning process.

The tests made so far on concentration of samples by panning lead to several conclusions. First, some samples have gold particles that cannot be recovered by panning because they float on the surface of the water; this is shown by the high gold content of some of the very fine size fractions. Second, some gold particles cannot be recovered because they are washed out during panning, either because they are very small or because they are attached to lighter grains that are washed out; analyses of a few of the "tails" fractions show about the same gold content as the bulk samples. Third, some panned concentrates yield more gold than is indicated by the bulk sample analysis. During some panning, this gold is visible, but commonly it is not; the invisible gold may be attached to or tied up in the structure of heavy minerals such as magnetite.

The gold that is recovered but not seen is finely divided and uniformly distributed so that analyses of replicate splits are in reasonable agreement. Visible gold particles, however, are few in number and so erratic in distribution that replicate analyses may give widely varying results.

Recovery of gold by panning is influenced not only by the uncertainties just discussed but also by the skill of the panner. In one test, a weighed amount of gold, in particles somewhat larger than the average flake observed in the natural samples, was added to 500 g of typical sample material, and the sample was then panned by two people. Recovery by one operator was about 40 percent and by the other about 24 percent. In view of the fact that problems of panning all result in loss of gold, it is not surprising that average recoveries from concentrates shown in table 9 are low.

Despite the low recoveries obtained by panning, we believe the effort is justified; gold missed in analysis of bulk samples is discovered in concentrates of some samples, and a crude knowledge is obtained of the particle size at various localities. For example, at localities 1 and 2, at the northwest end of the Teton Range, analyses of bulk samples indicated average gold contents of 64.8 and 145.4 ppb (11 and 23 cents per cu yd), respectively, but only 2.3 percent of the gold was recovered by panning at locality 1 and only 2.0 percent at locality 2. Practically no accessory heavy minerals were recovered at either locality. The very small particle size of gold suggests the possibility that gold precipitated after deposition of the conglomerate. If the gold is indeed not detrital at this place, then it may not be in many other areas of conglomerate in northwestern Wyoming.

Table 9.—Comparison of gold content in panned concentrates with that in unconcentrated samples

Locality No.	No. of samples panned	Au (ppb) recovered in concentrate by panning: Range <100 to-	No. of samples having >1,000 ppb	Average Au	Average in-place content of Au (ppb): Computed from Au recovered by panning	Indicated by analytical data (No. of samples in parentheses)		Percent of indicated Au recovered by panning
				Harebell Formation (Upper Cretaceous)				
9	24	14,400	2	690	2.8	31.3	(23)	8.9
10	25	38,000	10	4,930	19.4	43.3	(39)	44.8
11	36	17,900	9	1,200	5.0	99.7	(59)	5.0
12	7	400	0	165	.5	70.0	(10)	.7
31	6	1,000	1	225	1.0	83.2	(14)	1.2
	1/98	2/38,000	1/22	3/1,890	3/7.6	3/65.2	1/(145)	3/11.5
				Pinyon Conglomerate (Paleocene)				
2	8	3,500	3	994	2.9	145.4	(13)	2.0
5	75	30,900	15	2,160	10.8	75.4	(74)	14.3
6	17	40,000	7	3,620	15.9	203.0	(37)	7.8
7	20	55,000	8	5,210	14.1	52.9	(31)	26.7
17	7	250	0	65	.6	33.7	(33)	.2
18	46	16,700	13	1,730	9.8	50.4	(84)	19.4
31	11	6,000	2	750	1.9	73.2	(31)	2.6
32	44	50,800	10	2,660	11.5	112.7	(103)	10.2
33	25	28,500	9	2,770	15.6	116.3	(26)	13.4
34	35	55,100	11	3,880	21.8	151.0	(39)	14.4
4/35	16	38,500	8	4,610	23.9	30.2	(45)	79.1
4/35S	39	32,000	22	3,670	34.4	85.0	(30)	40.5
36	19	4,700	1	295	1.5	138.0	(20)	1.1
37	18	1,000	3	228	1.2	50.8	(24)	2.4
38	12	11,000	2	1,680	12.1	27.6	(31)	43.8
39	17	8,400	4	1,240	19.3	87.1	(31)	22.2
	1/409	2/55,100	1/118	3/2,480	3/14.1	3/86.0	1/(652)	3/16.4
				Fort Union Formation (Paleocene)				
52	14	4,000	5	710	3.8	35.4	(14)	10.7
				Lowest(?) Eocene conglomerate, Bighorn Basin				
53	26	24,000	9	2,500	10.4	94.4	(26)	11.0
				Wind River Formation (lower Eocene)				
40	16	3,000	3	3,000	3.4	220.0	(23)	1.5
41	2	4,500	1	2,250	50.0	227.0	(3)	22.0
42	11	40,400	6	6,260	54.1	223.2	(14)	24.2
	1/29	2/40,400	1/10	3/2,720	3/24.2	3/221.8	1/(40)	3/10.9
				Pass Peak Formation (middle(?) Eocene) of Eardley and others (1944)				
50	20	11,200	6	1,770	25.8	46.6	(25)	55.4
				Quartzite boulder conglomerate in Miocene(?) pyroclastic sequence				
1	18	10,000	3	840	1.5	64.8	(21)	2.3
				Quaternary deposits derived chiefly from the Harebell Formation, Pinyon Conglomerate, Wind River Formation, and Pass Peak Formation of Eardley and others (1944)				
3	3	5,000	2	2,370	18.3	228.0	(5)	8.0
4	5	21,000	3	7,700	101.0	615.8	(6)	16.4
7	5	2,520	3	9,000	13.6	64.6	(15)	21.1
8	14	23,500	8	4,360	58.7	71.0	(5)	82.7
15	14	2,800	1	200	1.9	104.6	(14)	1.8
16	15	10,900	4	1,250	6.5	65.0	(16)	10.0
5/20	35	12,000	7	1,000	5.2	44.0	(49)	11.8
5/20	15	18,100	8	3,600	21.6	107.0	(20)	20.2
24	7	6,800	3	2,140	11.7	88.8	(12)	13.2
45	6	7,500	2	1,750	6.6	188.7	(8)	3.5
46	7	<100	0	<100	<1.0	57.1	(7)	0
49	1	4,900	1	4,900	25.0	25.0	(1)	100.0
	1/127	2/23,500	1/42	3/2,050	3/17.5	3/98.3	1/(158)	3/17.8
				Pre-Harebell rocks (or alluvium derived therefrom)				
43	2	1,750	1	850	6.0	35.0	(2)	17.1
44	3	1,700	1	800	.7	132.5	(4)	.5
47	2	1,100	1	550	1.5	50.0	(2)	3.0
48	2	300	0	150	.5	<10	(2)	----
51	4	6,900	1	1,800	4.9	41.2	(4)	11.9
	1/13	2/6,900	1/4	3/980	3/2.4	3/21.3	1/(14)	3/11.2

1/Total. 2/Highest value. 3/Overall average. 4/Scarp. 5/River bottom.

The samples taken northwest of Upper Slide Lake (loc. 31), along the South Fork of Fish Creek (locs. 36 and 37), and from near Leeds Creek (loc. 40) likewise show low gold recovery from panned concerntrates. A majority of these samples are sandstone, shale, limestone, and coal; the sandstone contains abundant muscovite and biotite. One possibility is that gold of very small particle size (the size lost during the panning process) was deposited with the sediment in special environments at the sample sites; a second possibility is that colloidal gold or gold in solution was later deposited in some of these rocks.

Recovery of gold from samples at locality 35 (near North Fork of Fish Creek) is considerably higher than from samples at most localities, presumably because the gold is much coarser here than elsewhere in the region. The average gold content of the samples collected at stream level through a stratigraphic thickness of several hundred feet (samples from loc. 35, table 4) is only 30.2 ppb (5 cents per cu yd) compared with 85.0 ppb (14 cents per cu yd) for approximately the same stratigraphic interval on the adjacent face of the scarp (samples from loc. 35S, table 4). The actual gold content of the two groups of samples is probably more nearly the same than the analytical data suggest; the discrepancy is likely due to the difficulty in obtaining representative samples of material containing coarsely particulate gold. The reason for the much larger particle size of gold at this locality has not been determined.

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★ U.S. GOVERNMENT PRINTING OFFICE : 1967 O—264-416