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Gold in stream sediments from the Orange County copper district, east-central Vermont

by

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INTRODUCTION

New England is one of the few parts of the Appalachians without significant deposits of gold. The largest gold resources of this region probably are contained in stratabound sulfide deposits. However, only trace amounts of gold occur in these deposits, which were mined principally for copper, zinc, and (or) lead. Bedrock deposits in which gold is the major commodity, although common in the southern Appalachians (e.g., Pardee and Park, 1948), are rare in New England. In Vermont, the only significant bedrock occurrence of gold is in quartz veins of the Bridgewater-Plymouth area, along the eastern margin of the Green Mountain anticlinorium (Hitchcock and others, 1861, v. 2, p. 844-850; Perry, 1929[?], p. 62-63). The Plymouth area is also noteworthy as the only significant locale of placer gold production in Vermont. Other drainages in Vermont reportedly contain gold (Henson, 1982), but none have recorded placer production.

This paper is an outgrowth of a much larger study by the U.S. Geological Survey of the geochemistry of stream sediments in the Orange County copper district. Future reports on this subject will include details on the entire suite of metals in the sediments, and their statistical correlations. The present report is limited to a discussion of the gold in the sediments, and the implications for the potential of bedrock deposits of gold in the district.

THE ORANGE COUNTY COPPER DISTRICT

The mines of the Orange County copper district are well known in New England for their long history of copper production. The various mines (Fig. 1) exploited stratabound and dominantly stratiform bodies composed of massive pyrrhotite, chalcopyrite, and minor sphalerite and pyrite. Elizabeth, the largest mine, produced approximately 3.2 million tons of ore with an average grade of 1.8% Cu, 0.5% Zn, 0.16 oz/ton Ag, and 0.008 oz/ton Au (McKinstry and Mikkola, 1954; Howard, 1969; Annis and others, 1983). About 0.5 million tons of massive sulfide ore, probably with similar grades, was produced from the Ely or Copperfield mine (Smith, 1905; White and Eric, 1944). The northernmost mines of the district, in the Pike Hill area, yielded less than 0.1 million tons of copper ore. The small Orange and Gove mines near Strafford and the Cookville mine south of Pike Hill have no recorded production (White and Eric, 1944).

The massive sulfide deposits of the district are contained in a sequence of thick metasedimentary and minor metavolcanic rocks of Early Devonian (?) age (Fig. 1). Principal lithologies are, for the Gile Mountain Formation, quartz-mica schist and micaceous quartzite, and, for the Waits River Formation, calcareous mica schist and quartzose metalimestone and metadolostone(?). The Standing Pond Volcanics, a thin unit of fine-grained amphibolite and minor metamorphosed chemical sediments, occurs near the contact of the Gile Mountain and Waits River Formations. The massive sulfide deposits occur in all three of these formations, and therefore at several different stratigraphic levels. The Elizabeth and Ely deposits are both within the Gile Mountain Formation, whereas the Pike Hill deposits occur in the Waits River Formation; the small Orange, Gove, and Cookville deposits are entirely within the Standing Pond Volcanics. The massive sulfide deposits and their host rocks all are multiply deformed, and metamorphosed to the lower or middle amphibolite facies. The nearest plutonic bodies are the small Brocklebank granite west of the district (Fig. 1), and the Barre and Knox Mountain Granites to the north (see Doll and others, 1961).

GOLD IN STREAM SEDIMENTS

Sampling and analytical methods

Sediments in active streams were sampled by standard field procedures at 72 different locations (Fig. 2). Samples represent drainage basins containing all the major deposits of the district (Elizabeth, Ely, Pike Hill), as well as adjacent basins, some of which contain small prospects. At each site, a bulk stream sediment sample and a panned concentrate were collected. The samples of stream sediment consist of fine-grained loose detritus, sieved to minus 80 mesh prior to analysis. The panned concentrates, obtained with a 16-inch gold pan, are mainly a mixture of heavy minerals and small rock fragments. After sieving, the minus 10 mesh fraction of the concentrates was retained for study. Bromoform (sp gr 2.8) was used to separate minerals such as quartz, feldspar, and micas from the heavier minerals, which were retained and processed further. The strongly magnetic fraction (chiefly magnetite) was removed by hand magnet, and the remaining heavy minerals (e.g., garnet, rutile, tourmaline, zircon) were separated into slightly magnetic and non-magnetic fractions by the magnetic separator, set at 0.6 amps. These two fractions and the sieved stream sediments were analyzed for 31 elements by a semiquantitative 6-step emission spectrographic method (Myers and others, 1961; Motooka and Grimes, 1976), and for gold by quantitative atomic absorption. Gold was detected in 17 of the stream sediment samples and in 22 non-magnetic fractions of the panned concentrates. No gold was detected in any of the slightly magnetic fractions of the concentrates, which were not considered further in this study.

Distribution of gold-bearing samples

Gold was detected in samples from three principal areas of the district: 1) the Elizabeth mine area, 2) the Ely mine area, and 3) the Pike Hill area. In each of these areas, gold occurs in streams that drain mine dumps and workings. However, gold also occurs at many peripheral sites in these areas that apparently are unrelated to the deposits. The occurrence of gold in each area is discussed below.

Elizabeth mine area

In the Elizabeth mine area (Fig. 3) gold was detected in 3 of 13 stream sediments and 7 of 17 panned concentrates (Table 1). Values in the stream sediments range from the limit of detection in two samples (0.05 ppm), to a high of 0.15 ppm in a sample from southwest of Morrill Mountain. The gold-bearing concentrates contain from 0.07 ppm to a high of 3.0 ppm gold; gold was visible in sample 81-VT-12. The only sites where both the stream sediment (Fig. 4) and the panned concentrate (Fig. 5) contain detectable gold are restricted to the southwestern part of the area, south of

Morrill Mountain. The gold in two panned concentrates from east of Morrill Mountain (but west of Copperas Hill) is apparently unrelated to the workings (dumps, tailings) of the Elizabeth mine, which are located on the east slope of Copperas Hill.

Also unrelated to the Elizabeth mine is a gold-bearing panned concentrate (no. 81-VT-37) from east of Gove Hill. One other concentrate in this area, from the West Branch of the Ompompanoosuc River near its confluence with Fulton Brook (not illustrated), contains gold (0.40 ppm). This site is downstream from Copperas Brook and presumably reflects gold in the dumps and (or) tailings of the Elizabeth mine. Other samples from the West Branch of the Ompompanoosuc River but upstream from Copperas Brook (which drains the mine) lack detectable gold.

Ely mine area

Gold was detected in 3 of 12 samples of stream sediment and 3 of 11 panned concentrates from the vicinity of the Ely mine (Table 2). Analyzed gold in the stream sediment samples are at the limit of detection in two samples, and 0.25 ppm gold in the third. The two samples having the lower values are from south and west of the mine, from streams that drain areas containing minor sulfide prospects (Figs. 6 and 7). The sample containing the relatively high gold concentration (81-VT-59), is from the drainage basin that contains the Ely mine.

The gold-bearing panned concentrates (Fig. 8) are from the drainage basin containing the Ely mine and from two other basins to the west. The concentrate from the stream draining the mine workings has 6.9 ppm gold (Table 2). Another sample (81-VT-50), from a basin with a sulfide prospect, contains a trace of gold. A third gold-bearing concentrate, with 0.47 ppm gold, is apparently unrelated to any sulfide occurrences.

Pike Hill area

In the Pike Hill area (Fig. 9), gold was detected in 12 samples of stream sediment and 12 panned concentrates from 31 localities (Table 3). Only 3 stream sediments contain more than the analytical detection limit, samples 81-PH-14 at 0.50 ppm, 81-PH-15 at 0.35 ppm, and 82-VT-67 at 0.55 ppm. The gold-bearing panned concentrates commonly have more gold than the stream sediment samples, to as much as 41 ppm. Gold was visible in one concentrate, sample 81-PH-14. In general, the correlation between the occurrence and amount of gold in stream sediment samples and panned concentrates collected from the same site is poor.

The gold-bearing samples of the Pike Hill area are distributed irregularly. Stream sediment samples containing gold (Fig. 10) come mainly from northeast and southeast of the mine sites, and their gold content appears to be derived from the old workings. Two gold-bearing sediment samples, however, are not obviously related to the mines on Pike Hill. One of these, sample 81-PH-14, with 0.50 ppm gold, comes from a drainage basin entirely south of the mines. The other, sample 82-VT-67, with 0.55 ppm gold, is from a basin to the west.

Gold-bearing panned concentrates have a somewhat different distribution (Fig. 11). Most of the concentrates that contain gold were collected from streams close to the old mine sites, or in peripheral, apparently unrelated basins. The latter group includes sample 82-VT-74, with 2.4 ppm gold, from a drainage north of the mines; samples 81-PH-12 and 82-VT-64 from the southwest, having 2.9 and 5.6 ppm gold, respectively; and samples 81-PH-14 and 82-VT-82 from south of the mines, with 41 and 14 ppm gold, respectively. The southernmost gold-bearing concentrates, south of Cook Hill, (e.g., 81-PH-14), are from the few sites where gold was also found in stream sediments.

DISCUSSION

The distribution of the gold occurrences in the drainages of the district suggests a potential for bedrock deposits of gold. Although a glacial origin cannot be ruled out entirely, there is some evidence that the source of the gold is local. The gold-bearing drainage basins are aligned north-south, in contrast to the dominant southeast direction of glacial transport in the region (Larsen, 1972, 1975). The gold-bearing samples from south of Morrill Mountain, for example, are not southeast of any major mineralized areas, either within the district or outside of it to the northwest, which presumably would have been the source of any glacially transported gold. Therefore glacial transport is not believed to have affected the gold distribution in the district significantly, and the gold found is interpreted as being derived from local bedrock.

One possible source of the gold is massive sulfide deposits. Such deposits contain the only known concentrations of base metals, silver, and gold in the district. A study of the gold content of massive sulfide deposits from throughout the district (J. F. Slack and R. Moore, unpub. data) shows gold to be present in nearly half of the 33 samples analyzed. The 14 samples from the Elizabeth mine have an average concentration of 0.24 ppm gold (0.007 oz/ton), in general agreement with production records (McKinstry and Mikkola, 1954). At the other mines (Ely, Pike Hill, and Gove) gold is also detectable (>0.05 ppm) in massive sulfide, but the average values are lower than in the Elizabeth ore. The presence of gold in these deposits and in the drainage basins containing them suggests that the gold reported in this study from elsewhere in the district may be derived from massive sulfide. However, such massive sulfide deposits need not be extensions of the known orebodies, as, for example, in the Morrill Mountain area.

Gold might also be derived from sulfide-free rocks such as discordant quartz veins and various types of stratabound mineralization. Veins seem to be an unlikely source because veins carrying gold commonly were identified early by prospectors (e.g., Bridgewater-Plymouth, Vt.), and probably would already have been found in the district. Stratabound gold, however, is more difficult to recognize, particularly if sulfides are not part of the mineralization. Such mineralization is known from throughout the world, in which gold in places is associated with metamorphosed chemical sediments. Some metamorphosed chemical sediments are lithologically distinctive, such as chert, coticule, tourmalinite, and iron formation. All of these lithologies are present in the Orange County copper district (Annis and others, 1983; J. F. Slack and M. P. Annis, unpub. data). Metamorphosed chert, for example, occurs in the wall rocks of the Elizabeth and Pike Hill deposits, and locally in the Standing Pond Volcanics. Coticule, or fine-grained spessartine-rich rock (Renard, 1878), is present at several places in the Elizabeth mine sequence, and in the Standing Pond Volcanics. Tourmalinite (Slack and others, 1984) occurs at the Elizabeth and Ely deposits, and in the Gile Mountain Formation about 1 km east of the Elizabeth mine (Rolph, 1982; Plaus, 1983). Magnetite-quartz iron formation also occurs in the Standing Pond Volcanics at the Cookville mine (White and Eric, 1944) and near the Orange and Gove properties (J. F. Slack and M. P. Annis, unpub. data). The presence of these unusual lithologies in the district and their association with gold elsewhere (e.g., Sawkins and Rye, 1971; Fleischer and Routhier, 1973; Nicholson, 1980; Valliant and Barnett, 1982; Hallager, 1984) suggests that the metamorphosed chemical sediments of the area are another potential bedrock source of the gold.

CONCLUSIONS

Gold has been found in stream sediment samples and panned concentrates in the Orange County copper district, Vermont. Gold is present in samples from basins that contain the major mines of the district, and also in samples from several other areas. Some of these areas are peripheral to the drainage basins that contain the mines at Pike Hill, whereas other drainage areas near Morrill Mountain, Gove Hill, and west of the Ely mine, are not associated with known mineralization. The distribution of gold-bearing samples suggests that the gold is from local bedrock sources. The most likely sources are massive sulfide deposits and (or) metamorphosed chemical sediments. More detailed geochemical sampling will be required to locate specific sources of the gold, and determine the potential for economic gold deposits in the district.

ACKNOWLEDGEMENTS

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Table 1.-- Gold contents (in ppm) of drainage samples from the Elizabeth mine area.

Sample No.	UTM Easting	UTM Northing	Stream Sediment*	Panned Concentrate**
81-VT-1	14430	55280	ND†	N(.12)
81-VT-2	14870	54150	ND	N(.19)
81-VT-3	14850	54230	ND	N(.09)
81-VT-6	14840	53520	ND	N(.45)
81-VT-11	11320	54500	L	N(.05)
81-VT-12	11680	53190	L	0.45
81-VT-13	11590	53480	0.15	L(.07)
81-VT-14	11810	53340	N	1.9
81-VT-15	13390	54690	N	0.36
81-VT-16	13210	56730	N	0.07
81-VT-17	14150	53520	N	N(.18)
81-VT-18	16490	53000	N	N(.19)
81-VT-19	11530	56500	N	N(.44)
81-VT-20	15750	54560	N	N(.05)
81-VT-28	12190	56470	N	N(.27)
81-VT-36	17790	55850	N	3.0
81-VT-37	16930	55360	N	2.4

*Atomic absorption analyses by J. E. Gray, U.S.G.S.; L = detected at limit of detection (0.05 ppm); N = not detected.

**Atomic absorption analyses by A. A. Roemer, U.S.G.S.; detection limit variable (in parentheses), based on sample weight.

†No data.

Table 2.-- Gold contents (in ppm) of drainage samples from the Ely mine area.

Sample No.	UTM Easting	UTM Northing	Stream Sediment*	Panned Concentrate**
81-VT-50	17000	66830	N	L(.06)
81-VT-51	16970	66670	N	N(.11)
81-VT-52	15700	66880	N	ND†
81-VT-53	15650	66750	N	0.47
81-VT-54	15640	65550	L	N(.27)
81-VT-55	16740	64580	N	N(.05)
81-VT-56	17190	66430	N	N(.05)
81-VT-59	17830	66280	0.25	6.9
81-VT-60	17990	65890	0.05	N(.34)
81-VT-61	18560	65520	N	N(.20)
81-VT-62	18550	65820	N	N(.08)
81-VT-63	19420	65410	N	N(.10)

*Atomic absorption analyses by J. E. Gray, U.S.G.S.; L = detected at limit of detection (0.05 ppm); N = not detected.

**Atomic absorption analyses by A. A. Roemer, U.S.G.S.; detection limit variable (in parentheses), based on sample weight.

†No data.

Table 3.-- Gold contents (in ppm) of drainage samples from the Pike Hill area.

Sample No.	UTM Easting	UTM Northing	Stream Sediment*	Panned Concentrate**
81-PH-1	18750	78420	L	N(.10)
81-PH-2	17450	78140	L	9.0
81-PH-3	16130	79070	L	N(.5)
81-PH-4	16370	79100	L	6.0
81-PH-5	16400	80360	N	N(.30)
81-PH-6	17430	81530	N	N(.20)
81-PH-7	14890	81560	N	0.75
81-PH-8	14790	81580	N	7.5
81-PH-9	14590	81130	N	N(.30)
81-PH-10	15440	80540	N	7.2
81-PH-11	14720	80420	N	6.0
81-PH-12	14410	80330	N	2.9
81-PH-13	15220	80060	L	N(.40)
81-PH-14	17470	77950	0.50	41
81-PH-15	17640	81780	0.35	0.05
81-PH-16	16650	82280	L	N(.07)
81-PH-17	16760	83770	N	N(.07)
81-PH-18	18530	84210	L	N(.20)
81-PH-19	15970	83210	L	N(.05)
81-PH-21	19460	81300	N	N(.06)
81-PH-22	18620	81210	L	N(.11)
81-VT-63/64	12380	76390	N	5.6
81-VT-65/66	11980	79300	N	N(.05)
81-VT-67/68	12950	80600	0.55	N(.50)
81-VT-69/70	13530	80200	N	N(.10)
81-VT-71/72	13210	80040	N	N(.20)
81-VT-73/74	17250	85110	N	2.4
81-VT-75/76	14770	85690	N	N(.05)
81-VT-77/78	13520	84400	N	N(.05)
81-VT-81/82	14580	77690	N	14

*Atomic absorption analyses by J. E. Gray, U.S.G.S; L = detected at limit of detection (0.05 ppm); N = not detected.

**Atomic absorption analyses by A. A. Roemer and J. E. Gray, U.S.G.S.; detection limit variable (in parentheses), based on sample weight.

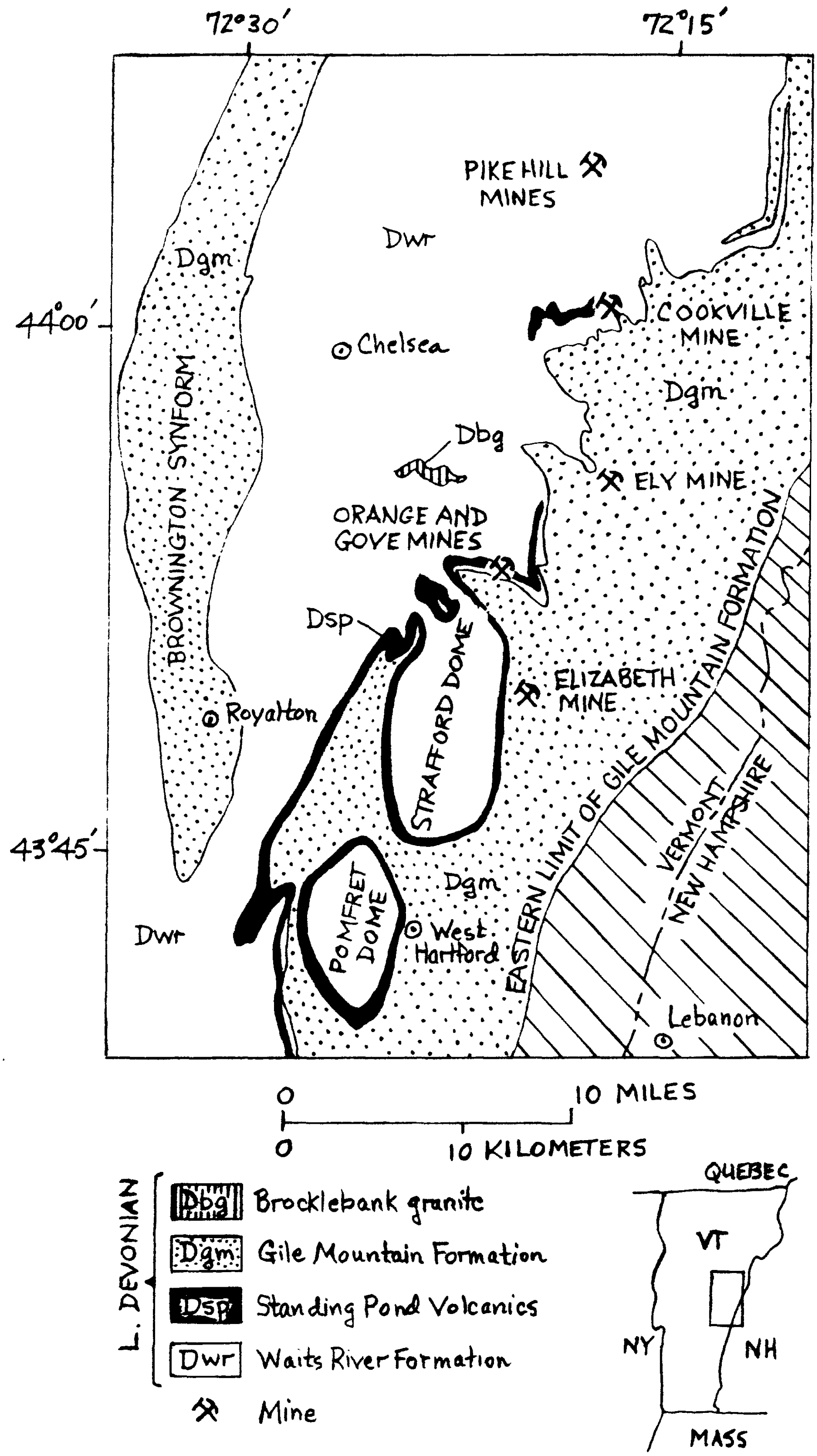

Figure 1.-- Geologic map of the Orange County copper district, Vermont. Geology after Doll and others (1961). Distribution of mines from White and Eric (1944).

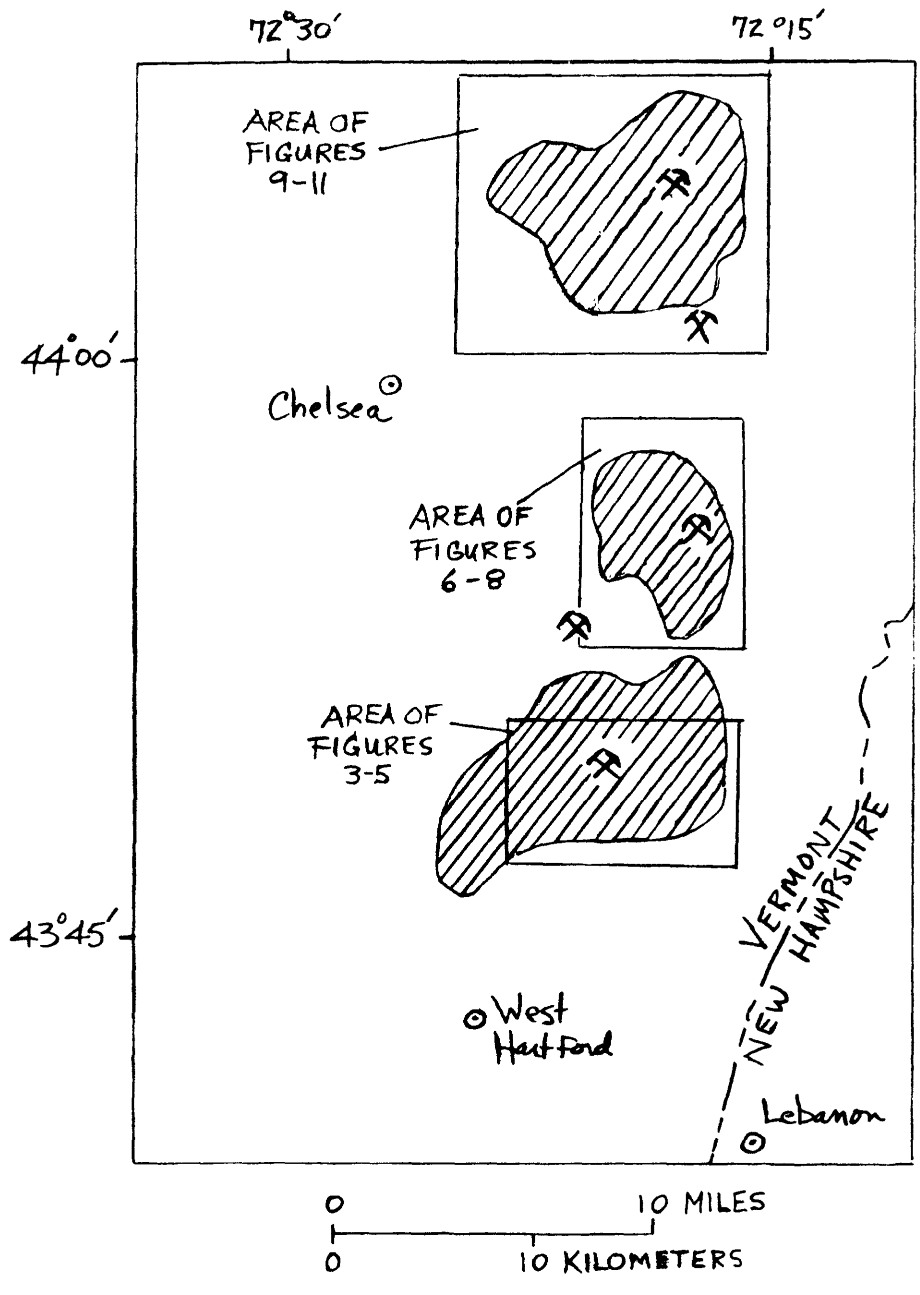

Figure 2.-- Map showing areas covered by geochemical drainage survey (ruled pattern) and principal mines of the district.

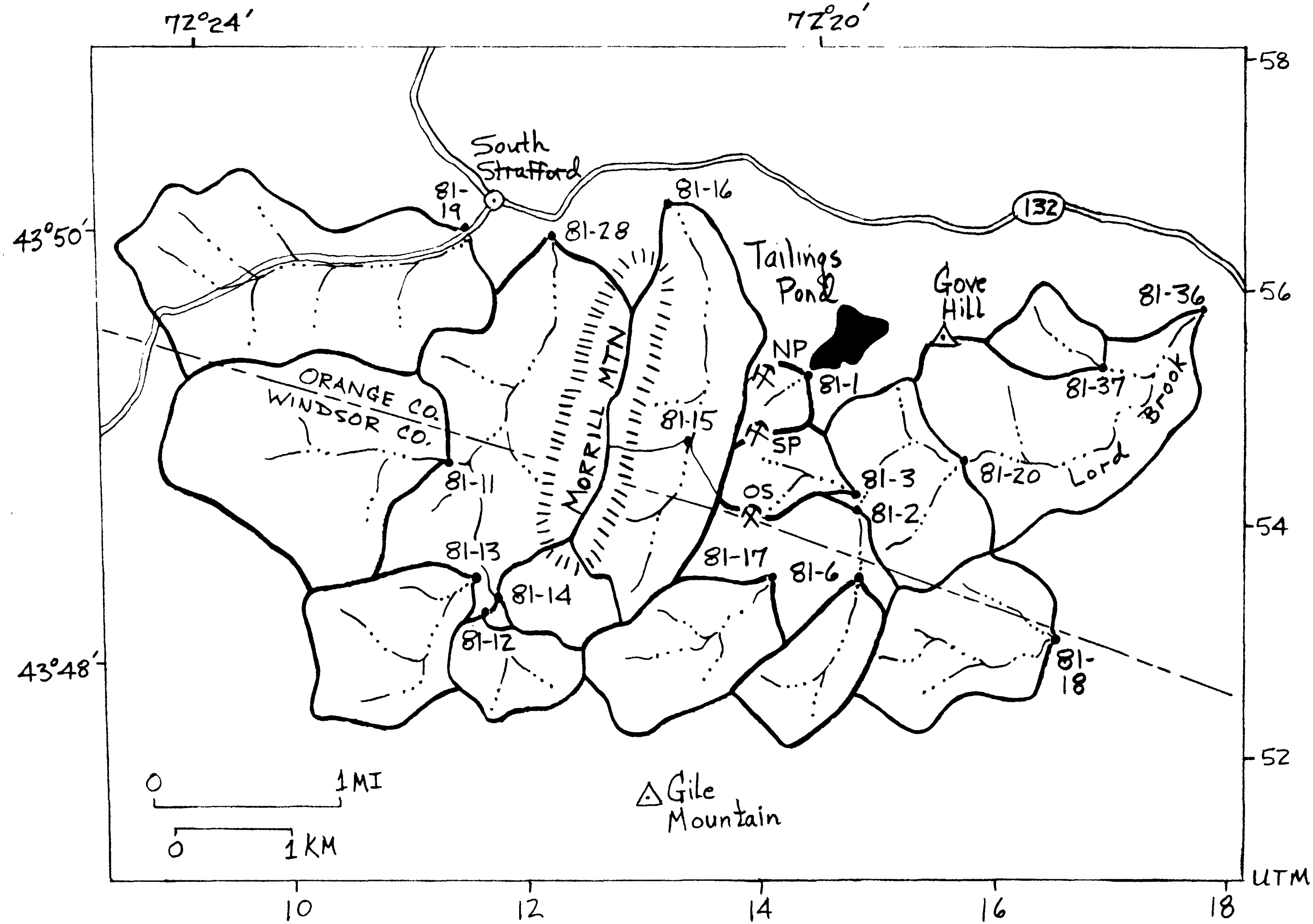

Figure 3.-- Map of the Elizabeth mine area, showing sample locations and respective drainage basins. Abbreviations for mine symbols: NP = North Pit; SP = South Pit; OS = Old South mine. See Table 1 for UTM (Universal Transverse Mercator) grid coordinates of samples.

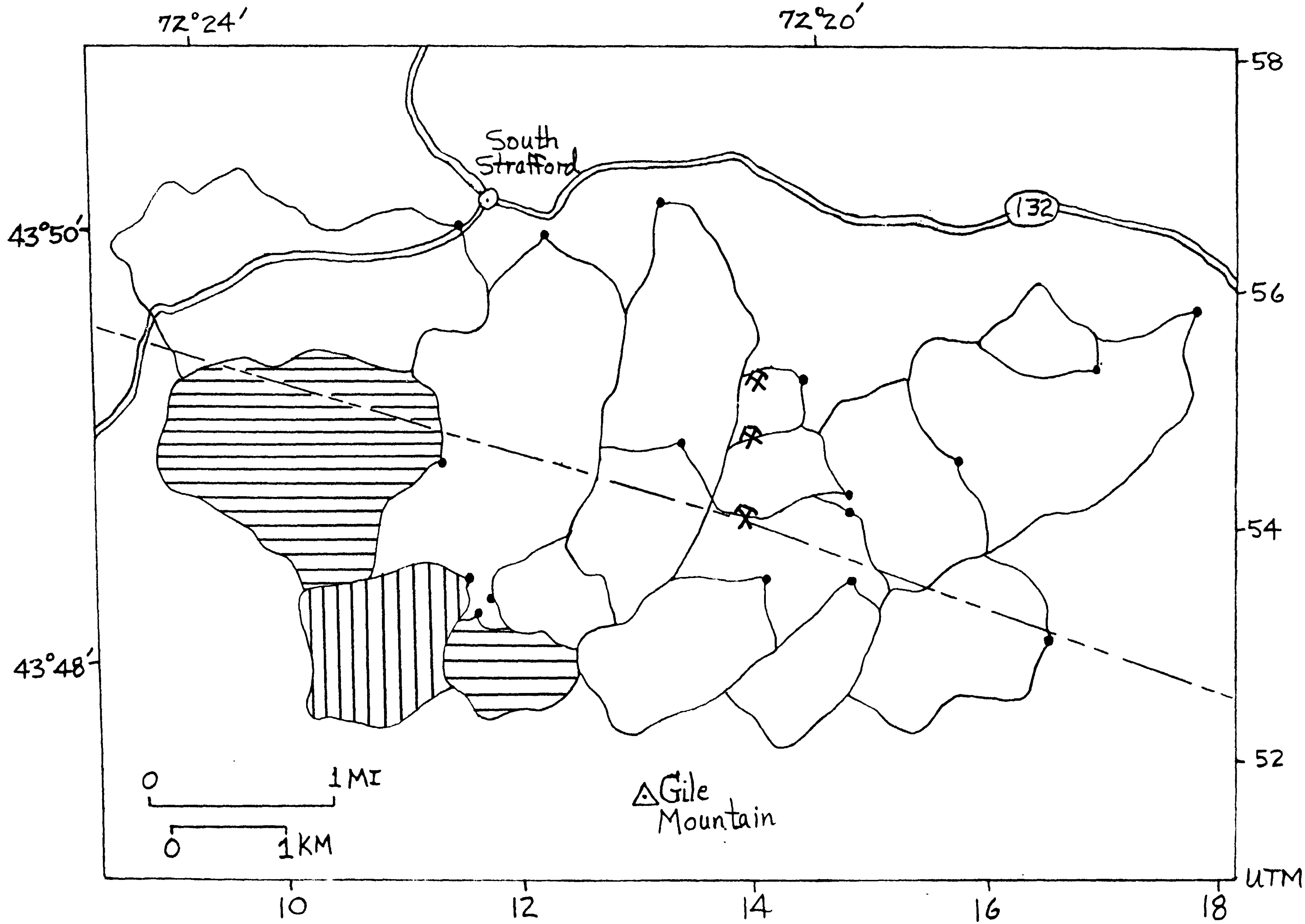

Figure 4.-- Map showing drainage basins containing gold in stream sediment samples in the Elizabeth mine area. Horizontal pattern = detected at limit of detection (0.05 ppm); vertical pattern = concentration greater than detection limit and less than 1.0 ppm gold. Unpatterned drainage basins have no detectable gold in stream sediment samples. See Table 1 for data.

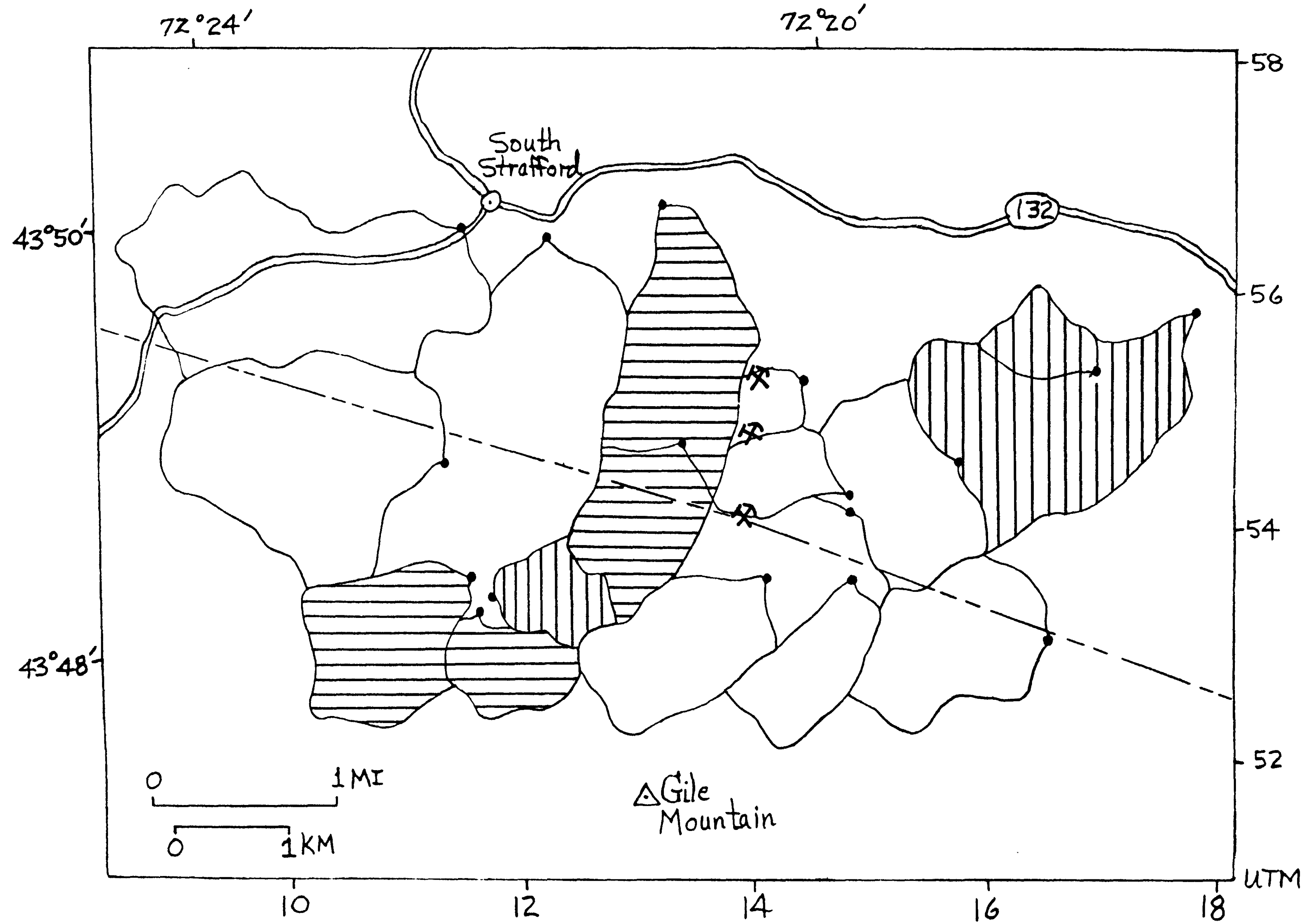

Figure 5.-- Map showing drainage basins containing gold in panned concentrate samples in the Elizabeth mine area. Horizontal pattern = detected at limit of detection (0.05 ppm) to 1.0 ppm; vertical pattern = concentration between 1.0 and 10.0 ppm gold. Unpatterned drainage basins have no detectable gold in panned concentrate samples. See Table 1 for data.

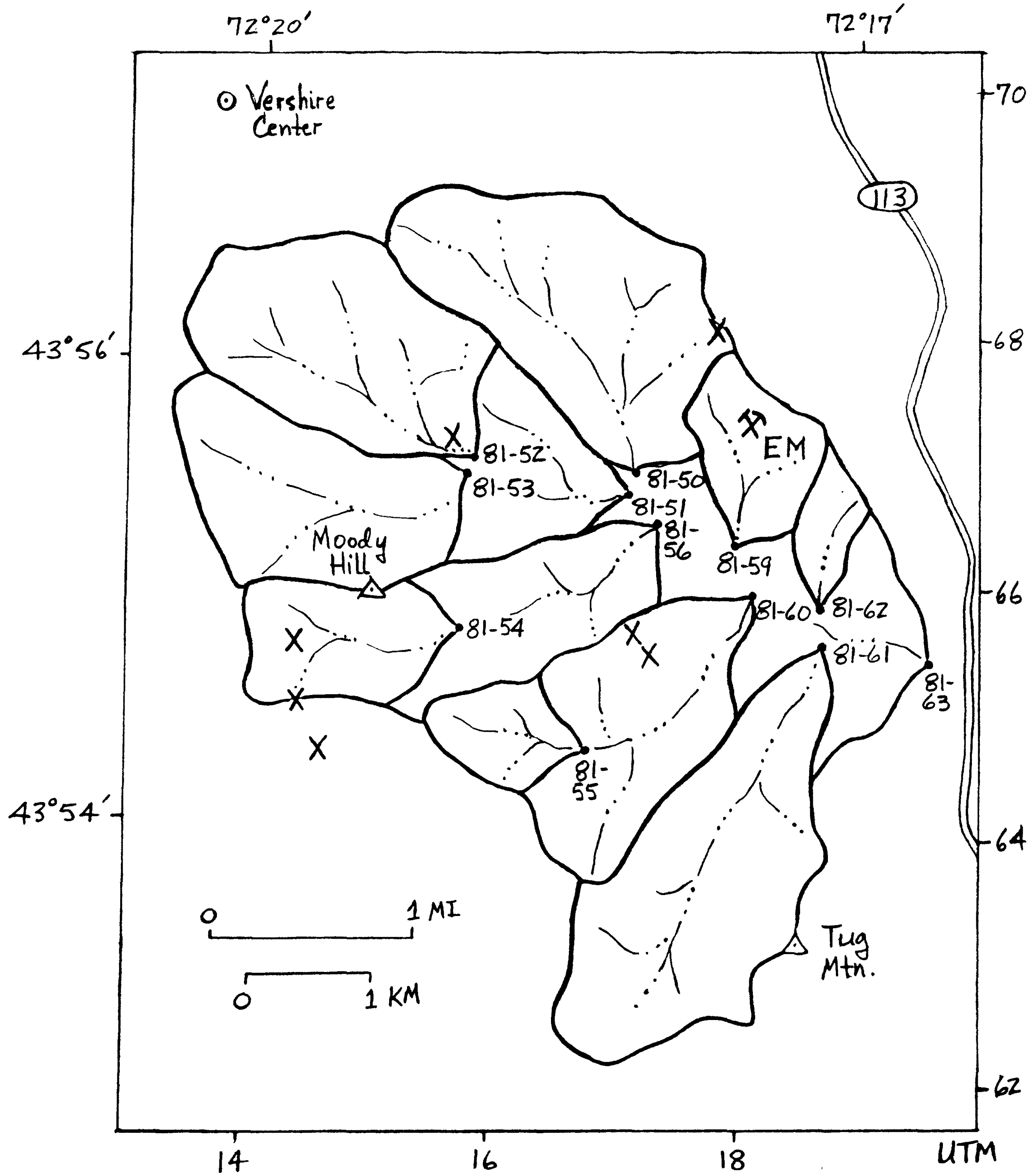

Figure 6.-- Map of the Ely mine area, showing sample locations and respective drainage basins. Abbreviation for mine symbol: EM = Ely mine. Distribution of prospects after White and Eric (1944). See Table 1 for UTM grid coordinates of samples.

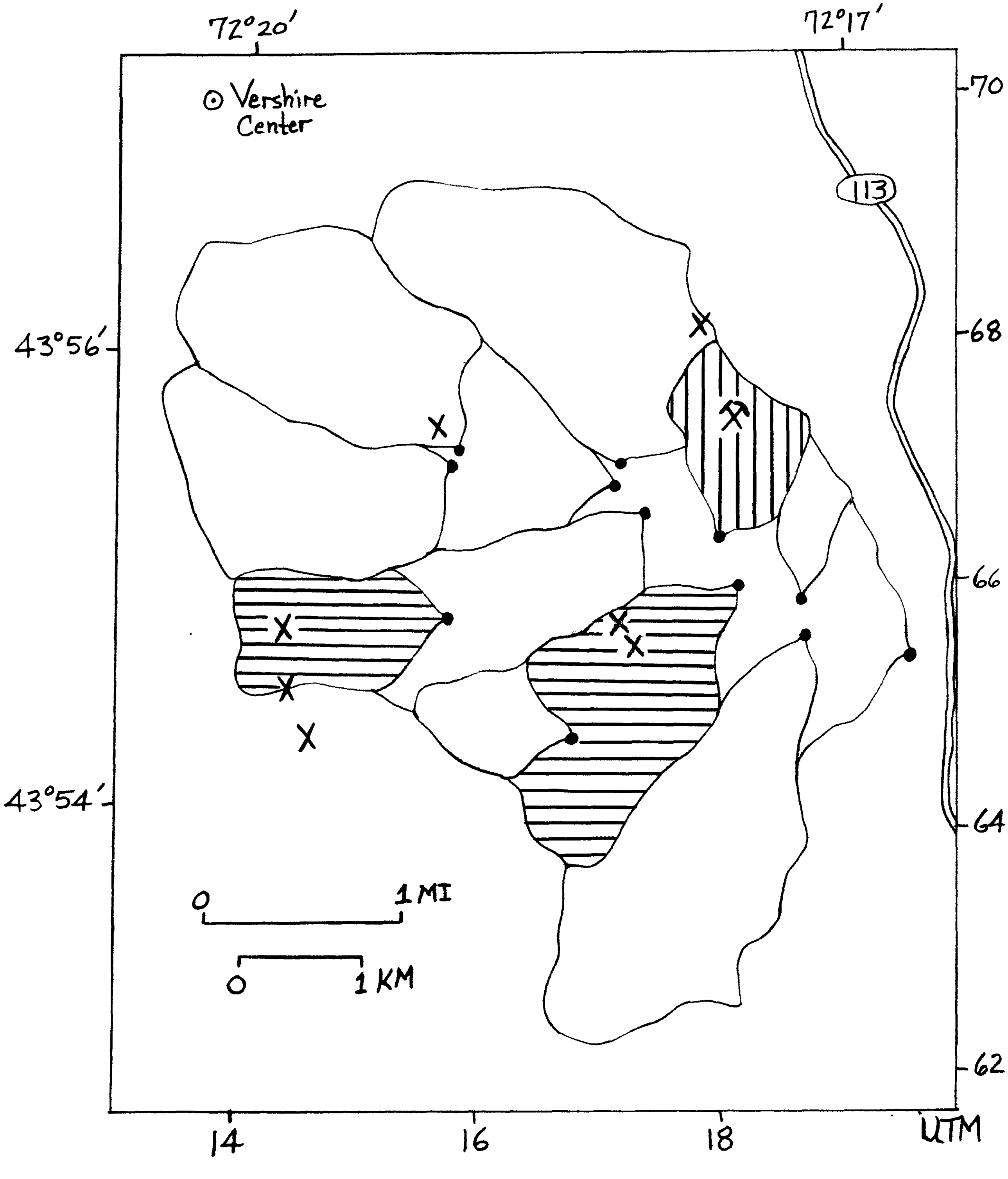

Figure 7.-- Map showing drainage basins containing gold in stream sediment samples in the Ely mine area. Patterns same as in Fig. 4. See Table 2 for data.

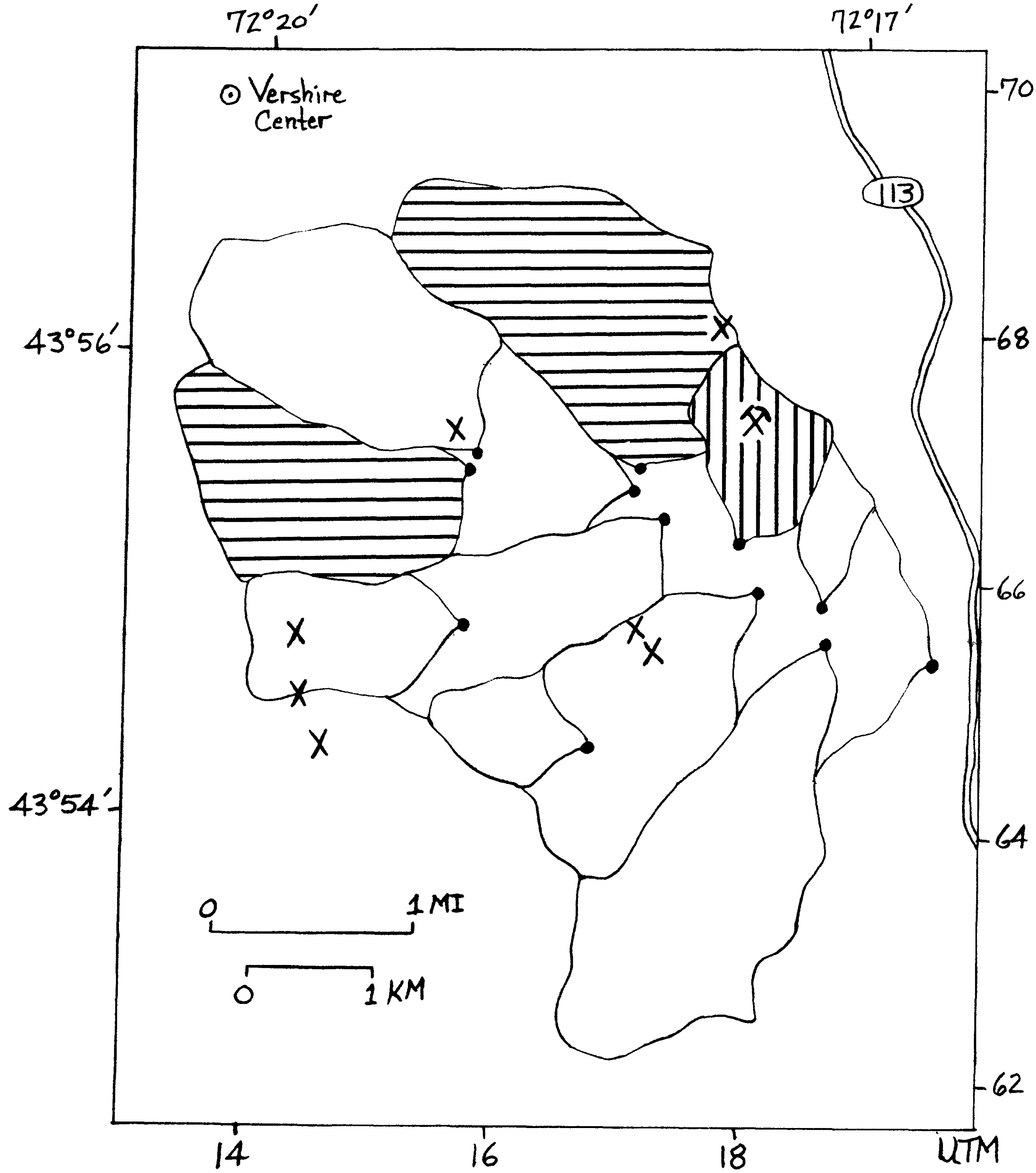

Figure 8.-- Map showing drainage basins containing gold in panned concentrate samples in the Ely mine area. Patterns same as in Fig. 5. See Table 2 for data.

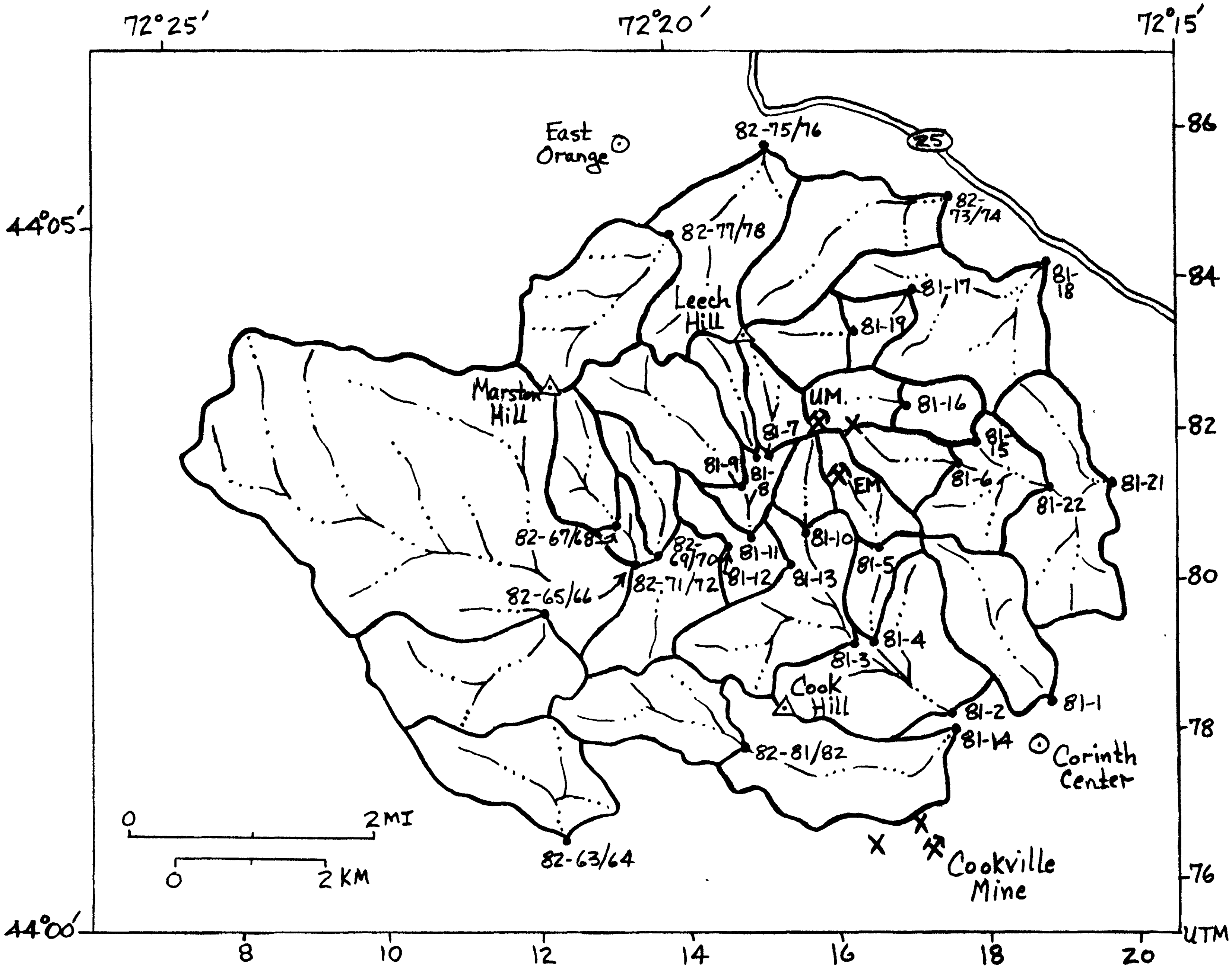

Figure 9.-- Map of the Pike Hill area, showing sample locations and respective drainage basins. Abbreviations for mine symbols: UM = Union mine, EM = Eureka mine. Distribution of prospects after White and Eric (1944). See Table 3 for UTM grid coordinates of samples.

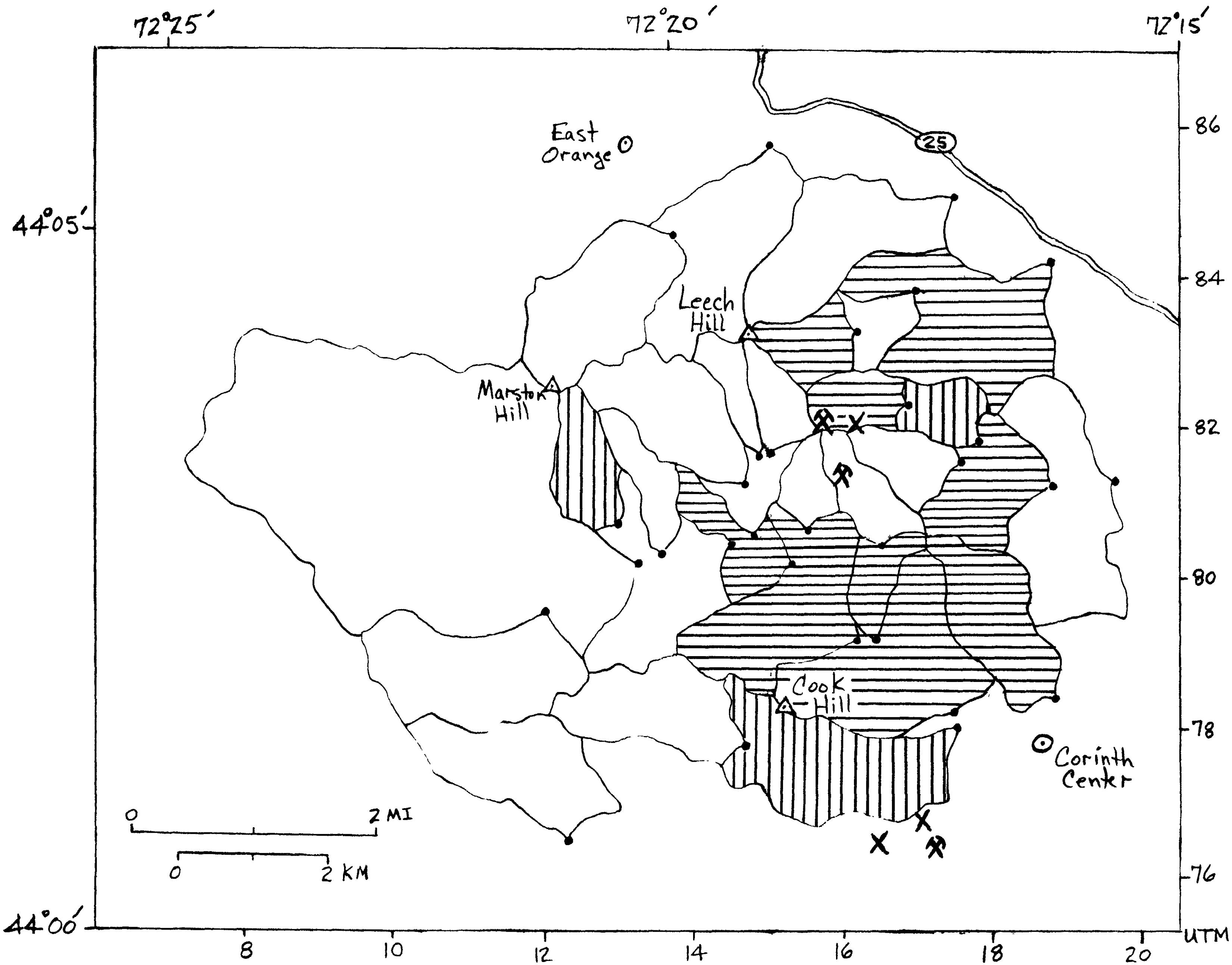

Figure 10.-- Map showing drainage basins containing gold in stream sediment samples in the Pike Hill area. Patterns same as in Fig. 4. See Table 3 for data.

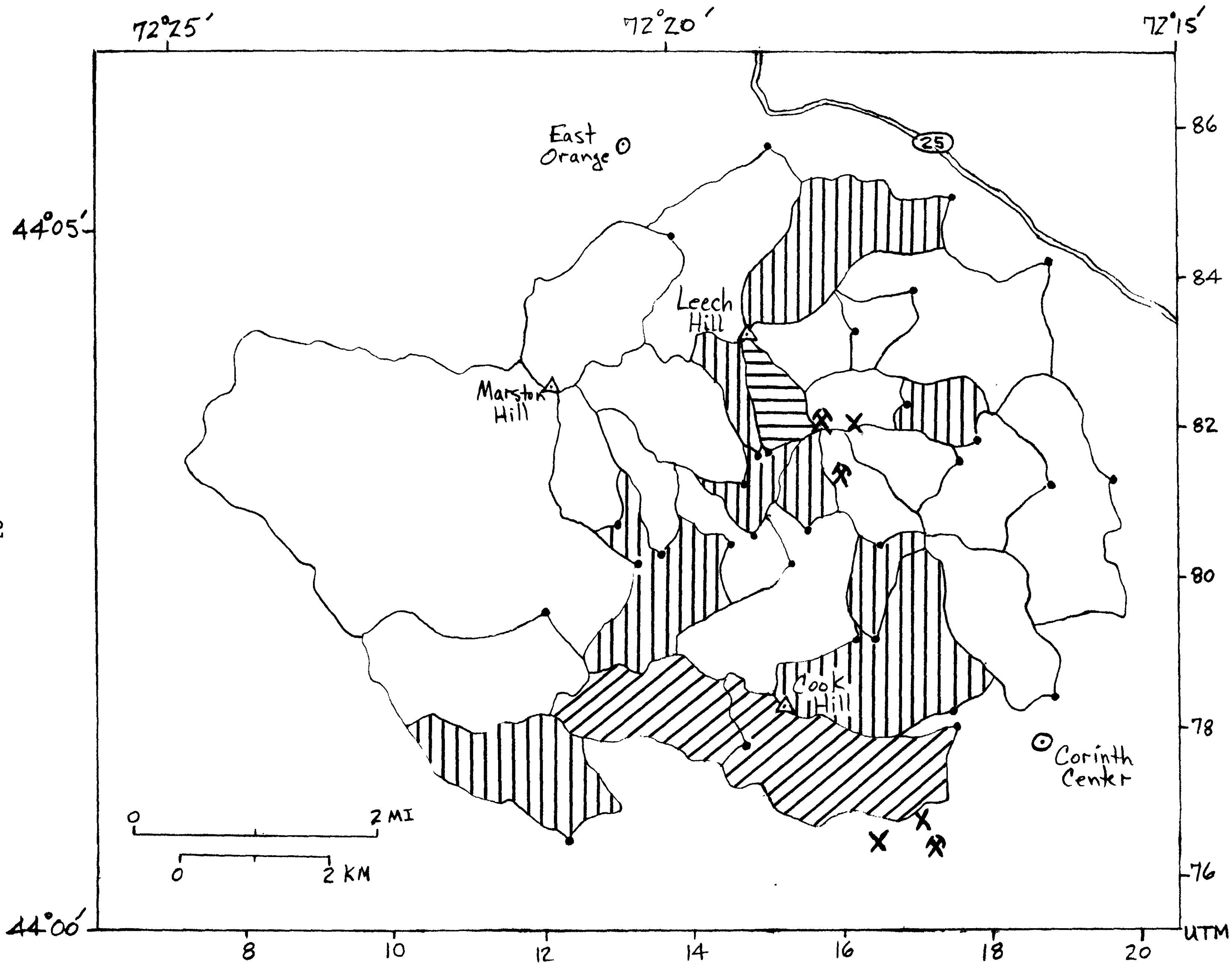

Figure 11.-- Map showing drainage basins containing gold in panned concentrate samples in the Pike Hill area. Patterns same as in Fig. 5, with addition of inclined pattern = greater than 10 ppm gold. See Table 3 for data.