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GEOLOGICAL SURVEY

Geologic, radiometric, and mineralogic maps and underground workings of the Schwartzwalder uranium mine and area, Jefferson County, Colorado

By

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

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DISCUSSION OF MAPS AND SECTIONS

Introduction

The Schwartzwalder uranium mine is about 8 miles (13 km) northwest of Golden in SE 1/4 sec. 25, R. 71 W., T. 2 S. in Jefferson County, Colorado (fig. 1). An area of approximately 1.3 mi^2 (3.4 km^2) with the Schwartzwalder mine at its center was mapped geologically and radiometrically at a scale of 1:6,000. A smaller area (0.1 mi^2 or 0.3 km^2) around the mine was previously mapped at a scale of 1:1,200 by Sheridan, Maxwell, and Albee (1967). Work by others in the Schwartzwalder mine area is cited in the reference list.

The Schwartzwalder deposit was recognized for its uranium potential in 1949 by Fred Schwartzwalder, now deceased, of Golden; it had been known, however, since the last century as a copper prospect. In 1953 the first ore shipments were made by Mr. Schwartzwalder, and in 1956 the Denver-Golden Oil and Uranium Co. purchased the property. In 1965 the Cotter Corporation acquired the property, and in 1974 the Cotter Corporation became the wholly owned subsidiary of Commonwealth Edison Company. Total production from the Schwartzwalder mine at the present time is approximately 9.6 million pounds (4.35×10^6 kg) U_3O_8, and the tenor of the ore delivered to the Cotter Corporation mill at Canon City is approximately 0.6 percent U_3O_8.

Triangulation points, and the mine grid were established by the Cotter Corporation and the locations of roads, trails, buildings, adits, and the mine shaft are based on their 1:1,200 maps. Elevations shown on the mine level maps and mine cross sections are those currently used in mine mapping. Recent rechecking of absolute levels by Cotter Corporation, Kenneth Segerstrom, and the author indicates that all mine levels should be adjusted by adding 51 feet (15.6 m) to them in order to conform with established benchmarks. I would like to acknowledge the cooperation of the Cotter Corporation staff, especially John Haley, in furnishing information for this report.

Location and geologic setting

The general location and geologic setting of the Schwartzwalder mine and four inactive uranium mines, North Star, Mena, Aubrey Ladwig, and Ascension are shown on figure 1. All of these mines are located in Precambrian gneisses and schists of the Idaho Springs Formation, and most are either on or very close to northwest-trending Precambrian faults. The Black Hawk, Junction Ranch, Hurricane Hill, Rogers, and Livingstone faults as well as the Idaho Springs-Ralston cataclastic zone are shown on figure 1.

The Black Hawk and Junction Ranch faults were shown by Taylor (1975) to have northeast sides up, and the Rogers and Livingstone faults have a similar movement sense (Sheridan, Maxwell, and Albee, 1967; Wells, 1967). On the contrary, the Golden fault shows the west block up, hence a scissors action evidently occurred along the Livingstone-Golden fault system. Displacements along the Hurricane Hill fault are small, but complex, according to Sheridan, Maxwell and Albee (1967). The Idaho Springs-Ralston cataclastic zone is of Precambrian age and may have acted as a barrier to uranium migration along the northwest-trending faults. According to Wells (1967) only minor occurrences of uranium have been found north of the zone. The Ralston dike consists of mafic monzonite that is of Paleocene age (61.9 2.5 m.y.; Marvin and others, 1974).

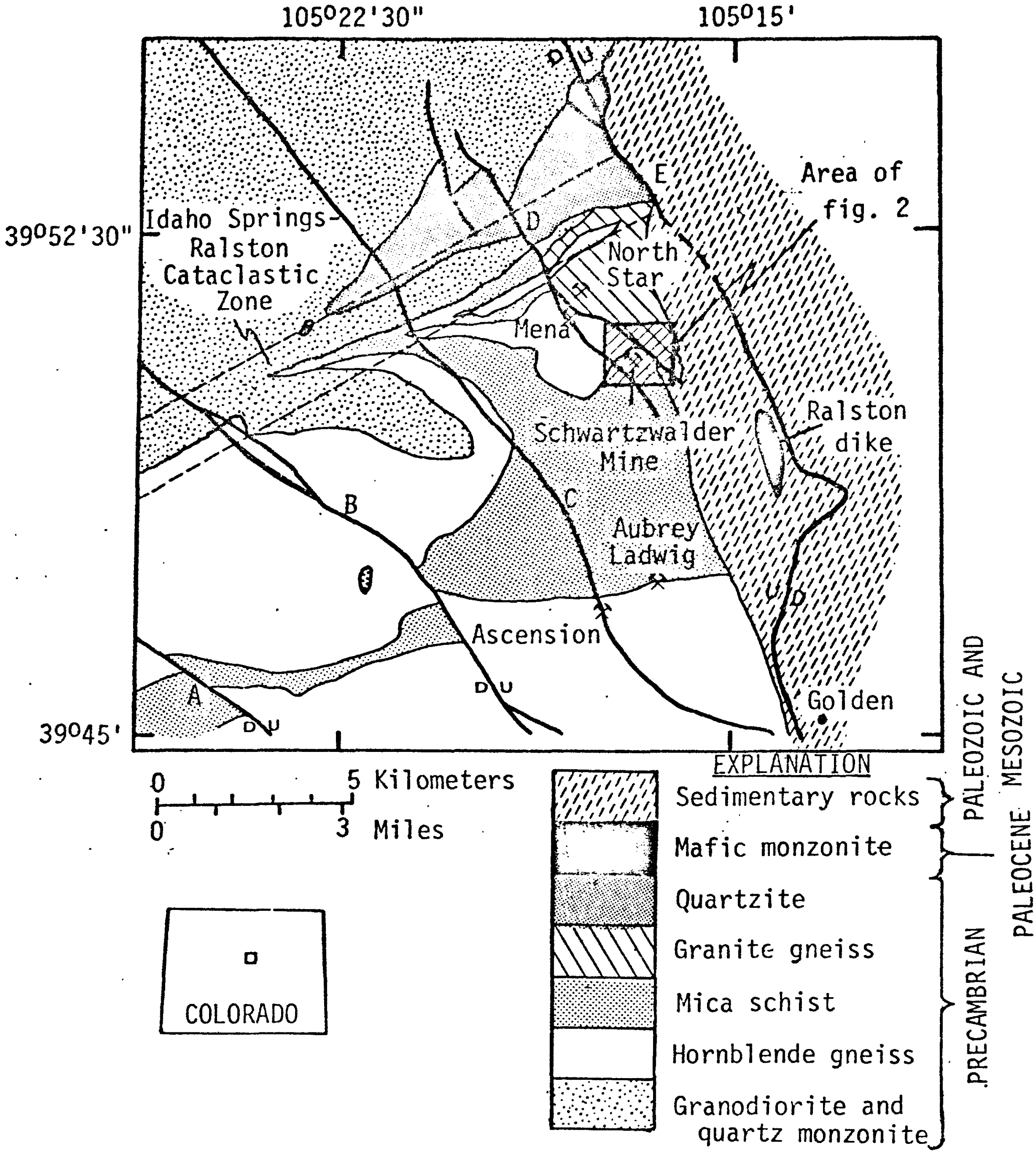

Figure 1.--Index map showing location of map area and regional geology.

Precambrian faults are identified as follows: A, Black Hawk; B, Junction Ranch; C, Hurricane Hill; D, Rogers, east and west branches; E, Livingstone (southern extension of Livingstone fault is known as the Golden fault[1] in Golden area). Idaho Springs-Ralston cataclastic zone outlined by dashed lines. (Modified from Taylor, 1975.)

[1]Although the Golden fault cuts post-Cambrian sedimentary rocks it probably has Precambrian ancestry according to Van Horn (1976).

Geology

Rock descriptions are given in the explanation. There is no evidence of lateral movement along Rogers fault east and little or no evidence along Rogers fault west (fig. 2). The hornblende gneiss unit (Xh) and the magnetite and quartz layer (Xm) are not displaced where they cross the east and west faults, respectively. Rogers fault east is presumably a reverse fault, but the vertical movement is of undetermined magnitude according to Sheridan, Maxwell, and Albee (1967) and I found no evidence for vertical displacement in excess of 10 m on either of the faults.

The geologic cross section A-A' (fig. 3) runs E-W along grid line 5,000 N. Foliations about 2,000 feet (610 m) south of section A-A' on figure 2 indicate that the schist forms a steeply dipping open synform that probably has an overturned west limb based on several westward-dipping foliations. Lineations indicate that the synform plunges WSW at moderate to steep angles (45°-68°). The northern portion of the open, plunging synform manifests itself both on the surface and underground by a compressed tongue of schist, partly garnetiferous, and quartzite that is transected by the through-going Illinois fault system. This tongue of schist, which is the host for most of the uranium in the Schwartzwalder mine, evidently represents the compressed apical part of the open synform, and by tracing out its axis on the surface to the northeast its structure is suggested by a tailing-out of the thin wedge of hornblende gneiss which encloses the schist tongue. The veins in the northwest quarter of figure 2 are probably an extension of the Illinois fault system as is the fault breccia at the unnamed adit in the southeast corner of figure 2.

Radiometry

Each rock unit mapped has characteristic radiometric readings (fig. 4) in counts per second (cps), which were measured on outcrops with a scintillometer (table 1). To evaluate cps in terms of equivalent uranium (eU) the following approximate relation is useful: 5 cps = 1 ppm eU as derived from analyzed rocks. The term eU represents the summation of radioactivity from the rock, and does not discriminate between contributions from uranium, thorium, and potassium. In general, in the Schwartzwalder mine area the relatively high readings shown on table 1 are almost entirely due to uranium and its daughter products.

Exposed veins and anomalously radioactive sites are also shown on figure 4. In the northwest corner of the map a vein in granite gneiss (Xgg) has a reading of 435 cps. A broad area of granite gneiss (Xgg) farther to the east is also notably radioactive (about 440 cps). Two anomalous radioactive highs were found in pegmatite (Xp); one, reading 600 cps, is in a fracture just northeast of Rogers fault east and the other reading 470 cps, is a diffuse area in the southeastern part of the map. A radioactive anomaly of 370 cps near the section corner in the central part of the map is the fault contact between Precambrian hornblende gneiss (Xh) and Pennsylvanian and Permian Fountain Formation (PPf). A vein reading 740 cps in mica schist (Xs) in a streambed in the south-central part of the map area is well exposed.

Mine geology

The remainder of the discussion pertains entirely to the Schwartzwalder mine. Host rocks for all of the pitchblende veins belong to the Idaho Springs Formation, a Precambrian metamorphic complex. Fissures, which now contain uranium, were opened or re-

Table 1.--Scintillometer readings in counts per second for rocks in the Schwartzwalder mine area

	Counts per second		Number of readings contributing to average
	Average	Range	
Bull quartz----------	55	50-60	3
Quartzite------------	57	35-180	11
Hornblende gneiss----	65	15-160	183
Magnetite and quartz-	90	-----	1
Pegmatite------------	131	75-275	92
Aplite in hornblende-gneiss	175	120-300	5
Mica schist----------	181	120-290	286
Fountain Formation---	242	150-360	32
Granite gneiss-------	255	160-440	90
Fault breccia (in hornblende gneiss	112	55-205	16
Fault breccia (in granite gneiss)	221	140-300	10
Fault breccia (in mica schist)	225	155-320	6

opened during Laramide uplifting and lead-uranium isotopic ages of around 60 m.y. were determined on the pitchblende (Marvin and others, 1974).

Five different rock types have been recognized in the mine. They are mica schist (Xs), garnetiferous schist (Xgs), hornblende gneiss (Xh), quartzite (Xq), and pegmatite (Xp). Lenses and interbanding of the rock types, especially the mica schist and hornblende gneiss, are common. In general, all of the rocks except pegmatite are remarkably fine grained.

The average modal mineralogy of the rocks studied, except for pegmatite, are expressed as volume percentages, and are given in table 2. Much of the data on the maps of the Charlie, Minnesota, and Upper levels are from Sheridan, Maxwell, and Albee (1967), with some new additions. Data on all other levels were gathered by geologists from the Cotter Corporation and by me. Data concerning veins in stopes between levels were obtained from the Cotter Corporation. Levels and stopes below the 8th level are being developed and their geology may require modification.

There is a very persistent westerly dip of about 75° of both foliation and rock units in the mine with only minor local exceptions. This can be seen on the cross sections (figs. 5, 6, 7, and 8). The veins occur in fissures and in this report the term, vein-fissure, will be used following the usage of Sheridan, Maxwell, and Albee (1967), wherein vein-fissures are defined as faults that contain pitchblende-bearing veins. The major vein-fissure systems strike about N. 15° W.; the longest and most persistent is the Illinois, which dips west about 75°. Drill data suggest that in plan view the extended Illinois vein-fissure system is in the shape of a cymoid loop or S-curve. Most of the production of uranium comes from offshoots that dip eastward on the hanging wall side. In

Table 2.--Average modal mineralogy

[Shown in volume percentages. Tr., trace; leaders (--) indicate not present]

Map symbol	Xs	Xgs	Xh	Xq
Quartz--------------	37	27	23	80
Biotite-------------	35	26	12	--
Muscovite-----------	14	9	4	6
Hornblende----------	--	2	27	1
Garnet--------------	2	26	Tr.	--
Plagioclase---------	3	1	9	--
Potash feldspar-----	3	1	3	--
Tremolite-----------	--	3	--	--
Epidote-------------	--	--	7	--
Diopside------------	--	--	6	--
Chloride------------	1	2	--	Tr.
Pyrite--------------	3	2	Tr.	2
Calcite-------------	1	Tr.	8	10
Black opaque--------	Tr.	1	Tr.	1
Leucoxene-----------	Tr.	--	--	Tr.
Apatite-------------	Tr.	Tr.	Tr.	Tr.
Sphene--------------	Tr.	--	1	--
Thin sections contributing to average-	8	6	6	6

general, these vein-fissures (offshoots) dip 10°-60° and steepen as they approach the Illinois vein-fissure system. The importance of the geometric disposition of the vein-fissures may be seen from the following overall ore production estimate made by Mr. John Haley: 50 percent of the ore is derived from steep hanging wall faults (>45°, 35 percent of the ore is derived from the Illinois fault, and 15 percent of the ore comes from "flat" veins (generally 15° to 25°). Post-ore movement along the fault-vein systems is evidenced by slickensides in much of the ore, but the total displacement is probably not large. Sheridan, Maxwell, and Albee (1967) record fault displacements of less than 6.5 feet (2 m) in the mine and concluded that the character of the movement in the Illinois system is not known. Intense alteration in the Illinois vein-fissure system and post-mining efflorescence of minerals inhibit observation, but my views are compatible with that of earlier work in the mine. The cross sections (figs. 5, 6, 7, and 8) and level maps (fig. 9) show only the largest vein-fissures. Most vein-fissures have subsidiary vein-fissures in their vicinity; this effectively widens the ore-bearing zone in the Schwartzwalder mine.

The ore deposit is entirely fracture-controlled. Pitchblende, the predominant ore mineral, is confined to vein fissures and their breccia zones in the hanging wall of the Illinois fault and in the Illinois fault itself, but not continuously. Lesser amounts of sulfides, such as galena, jordisite, molybdenite, and sphalerite accompany the pitchblende, which occurs as vein fillings or coats breccia fragments.

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EXPLANATION

Qal	ALLUVIUM (QUATERNARY)
PPf	FOUNTAIN FORMATION (PENNSYLVANIAN_PERMIAN)--Pink to reddish-orange arkosic sandstone and conglomerate, and dark reddish-brown sandstone
	IDAHO SPRINGS FORMATION (PRECAMBRIAN X)--Lithologic units--order does not necessarily reflect age
Xqt	Quartz vein--White fine- to coarse-grained bull quartz; nonconformable to schistosity of host rock
Xp	Pegmatite--Coarse grained; contains quartz, microcline, perthite, and mica
Xs	Mica schist--Very fine to medium grained; composed of quartz, biotite, muscovite and feldspar; locally contains garnet, andalusite, staurolite, sillimanite, or tourmaline; minor pyrite common in mine, where unit has been called quartz biotite schist
Xgs	Garnetiferous schist--Fine to medium grained; composed of quartz, biotite, garnet and muscovite; minor pyrite common in mine, where unit has been called garnetiferous biotite gneiss; mapped as variant of Xs only in the mine
Xm	Magnetite and quartz layer--Alternating layers of magnetite and quartz in schist as much as 4.5-6 m in thickness; most of layer unexposed but magnetite float as much as 20 cm across found on surface
Xq	Quartzite--Gray to white, fine to medium grained and foliated; may contain moderate amounts of calcite, muscovite, and traces of other minerals; minor pyrite common in mine
Xh	Hornblende gneiss--Fine to medium grained; composed of hornblende and plagioclase; generally unaltered but may contain calcite, epidote, and diopside, especially in the mine, where it has been called lime silicate hornblende gneiss
Xgg	Granite gneiss--Pink to pinkish-gray, very fine to fine grained; contains quartz, microcline, and plagioclase, and locally moderate amounts of biotite; occasionally found as conformable lenses of aplitic texture in Xh

Very fine grained = <0.1 mm
Fine grained = 0.1-1 mm
Medium grained = 0.1 mm
Coarse grained = >10 mm

GEOLOGIC CONTACT--Dashed where approximately located; dotted where inferred; queried where uncertain

STRIKE AND DIP OF FOLIATION

60 Inclined

Vertical

45 BEARING AND PLUNGE OF LINEATION--May be combined with symbols for planar structural features; lineations include subparallel alinement of elongate minerals or mineral aggregates, streaking, rodding, and the axes of crinkles and crenulations

45 PITCHBLENDE VEIN-FISSURE, SHOWING DIP

75 FAULT OR FRACTURE, SHOWING DIP--Dashed were approximately located

MINE SHAFTS--Shown only on mine maps

No. 1

No. 2

No. 3

TIMBERED ADIT OR DRIFT--Shown only on mine maps

NOTE: More important vein-fissures identified by name or number on mine level plans and sections

45 STRIKE AND DIP OF SEDIMENTARY BEDS

FAULT BRECCIA ZONE--Silicified breccia zone and breccia cemented by carbonate minerals and potassic feldspar

435 220 RADIOMETRIC READING--Measured in counts per second (cps); localities ≥350 cps are circled

600 RADIOMETRIC READING ON VEIN

CULTURAL FEATURES--Shown only on areal maps

Triangulation point

Building

Inclined shaft

⟩—— Adit--1, Steve; 2, Charlie; 3, Minnesota; 4, LBJ; 5, Upper; 6, Vent; 7, Montana; 8, Unnamed

Settling pond

==== Road

---- Trail

MINERALOGIC DATA

Minerals found in pegmatite

ap	Blue apatite
apa	Green-red apatite
cl	Cleavelandite
Q	Well-developed quartz core
T	Tourmaline crystals, variety schorl
	Minerals found in mica schist as metacrysts
a	Andalusite
g	Garnet (less frequently found in hornblende gneiss)
s	Sillimanite
st	Staurolite
	Moderate concentrations found in hornblende gneiss
e	Epidote
k	Potassic feldspar
	Other minerals or rock types
apl	Granite gneiss lens of aplitic texture found in hornblende gneiss
c	Calcite concentrations found in hornblende gneiss and fault zones
Cu	Malachite staining (indicating copper)
fb	Fault breccia
h	Hornblende found in minor amounts in granite gneiss or mica schist
m	Magnetite abundant as accessory mineral
M	Massive magnetite found in magnetite and quartz layer
py	Pyrite
q	Vein quartz, common
qt	Bull quartz vein
t	Tourmaline; fine grained, as selvage to pegmatite; may be moderate component of mica schist

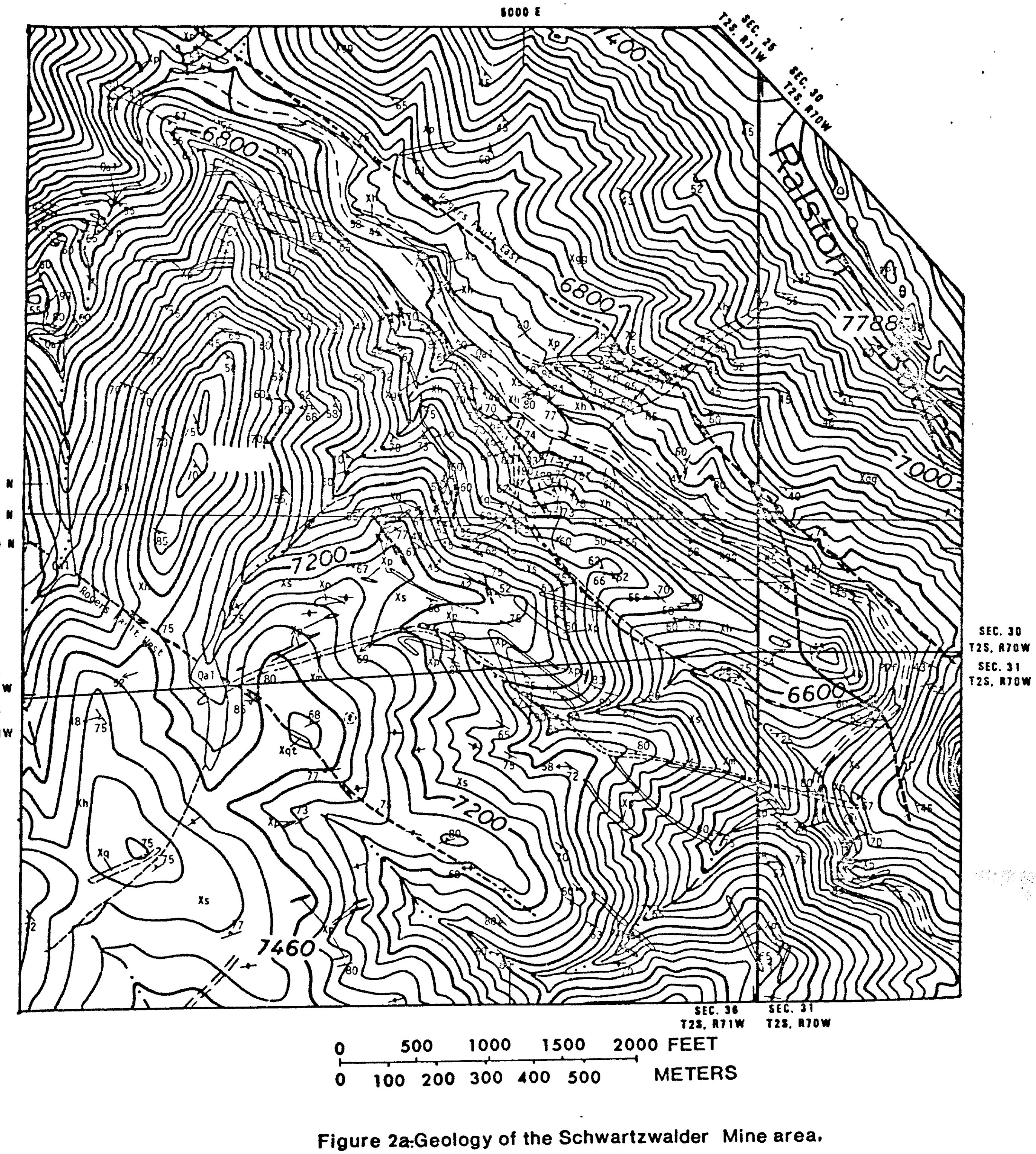


Figure 2a-Geology of the Schwartzwalder Mine area, Jefferson County, Colorado

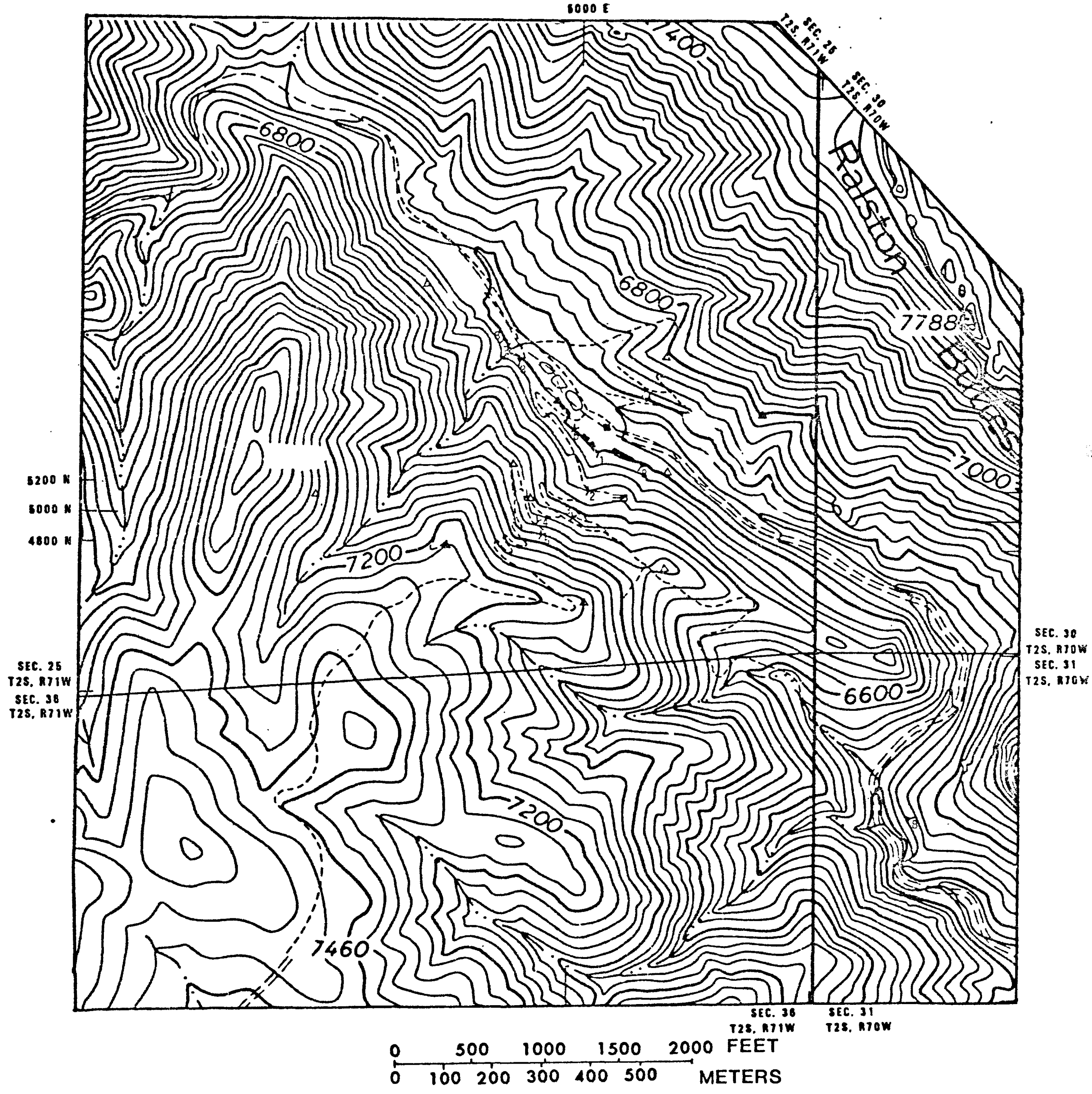


Figure 2b - Culture features of Schwartzwalder Mine area, Jefferson County, Colorado

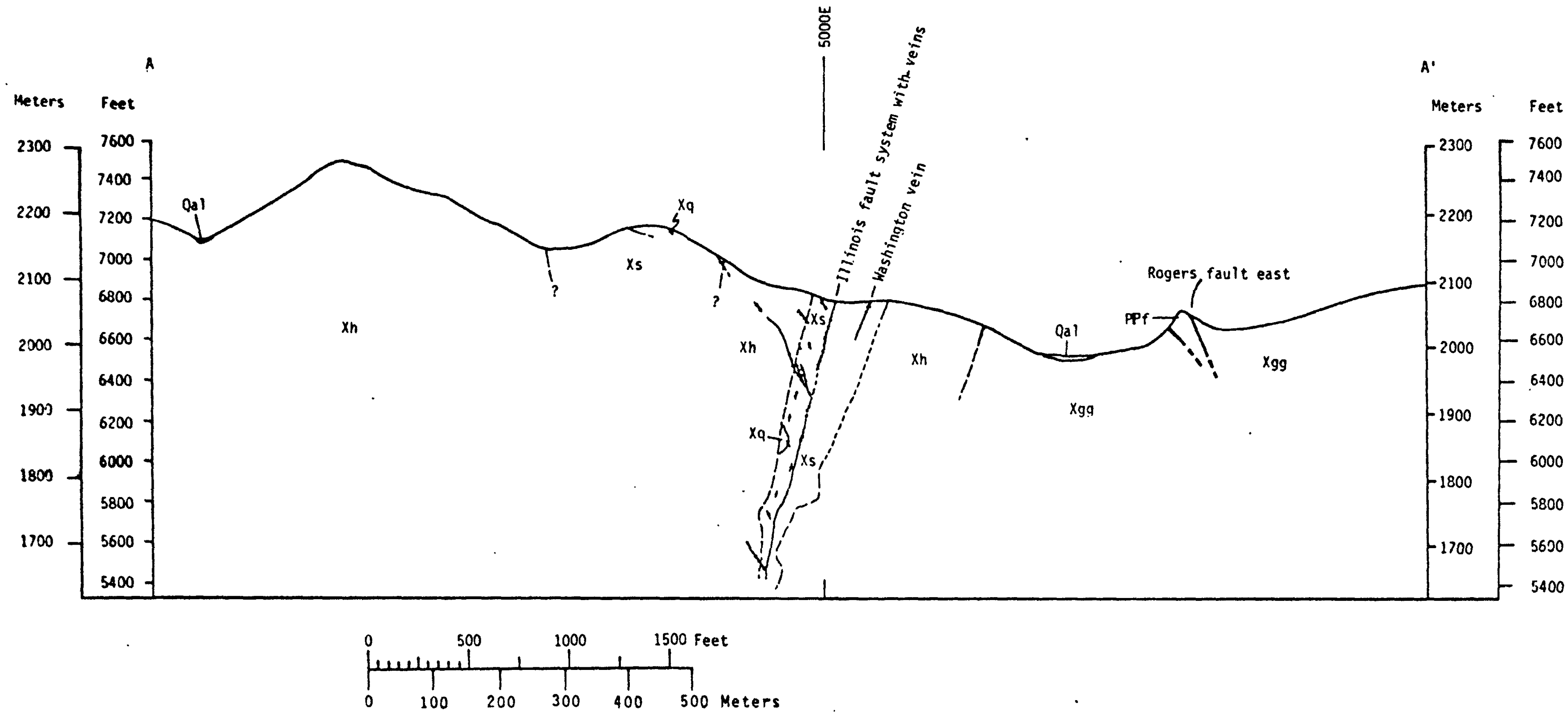


Figure 3. - Cross section A - A'

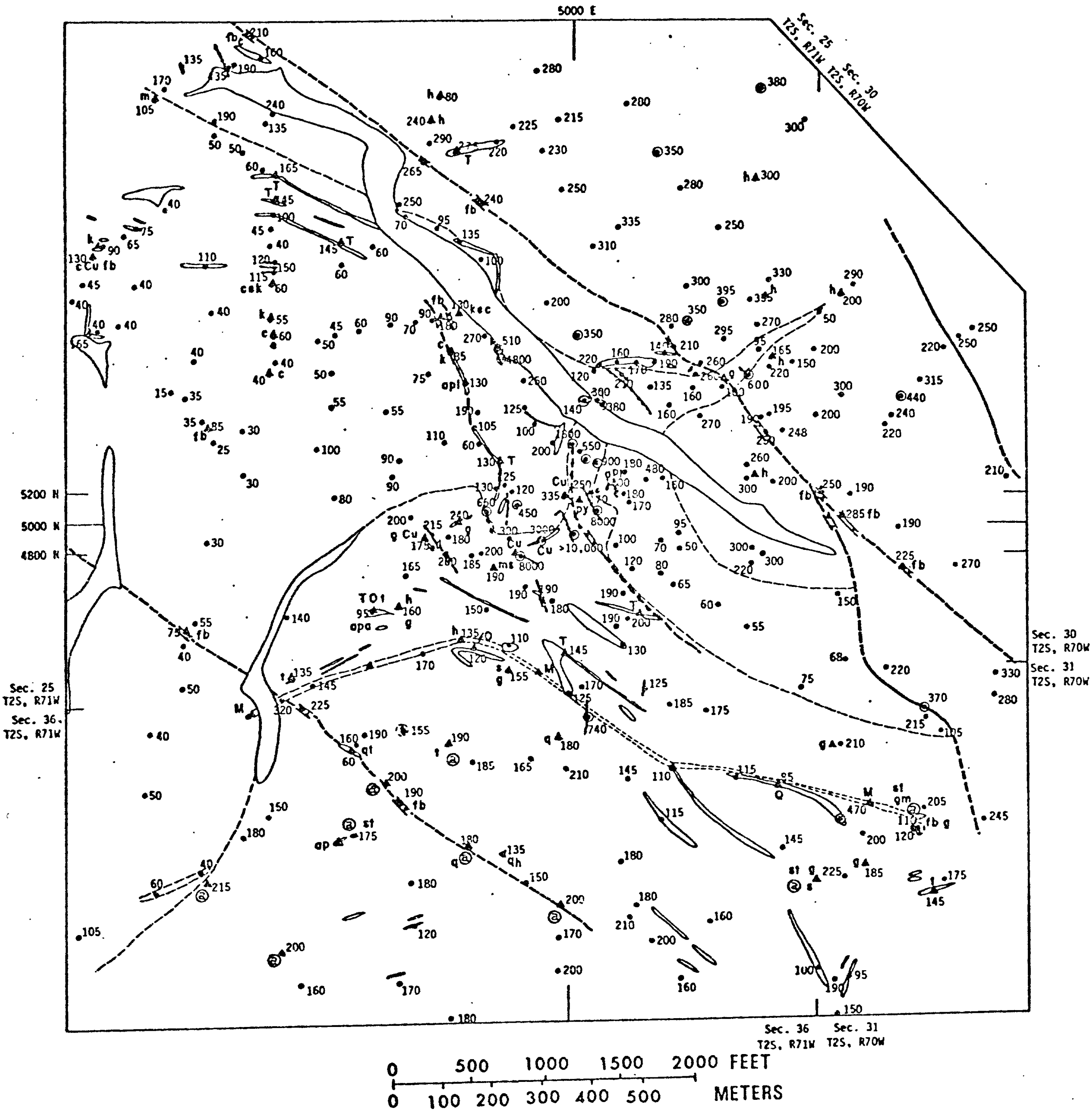


Figure 4- Mineralogic data(▲) and radiometric data(•) present in Schwartzwalder Mine area

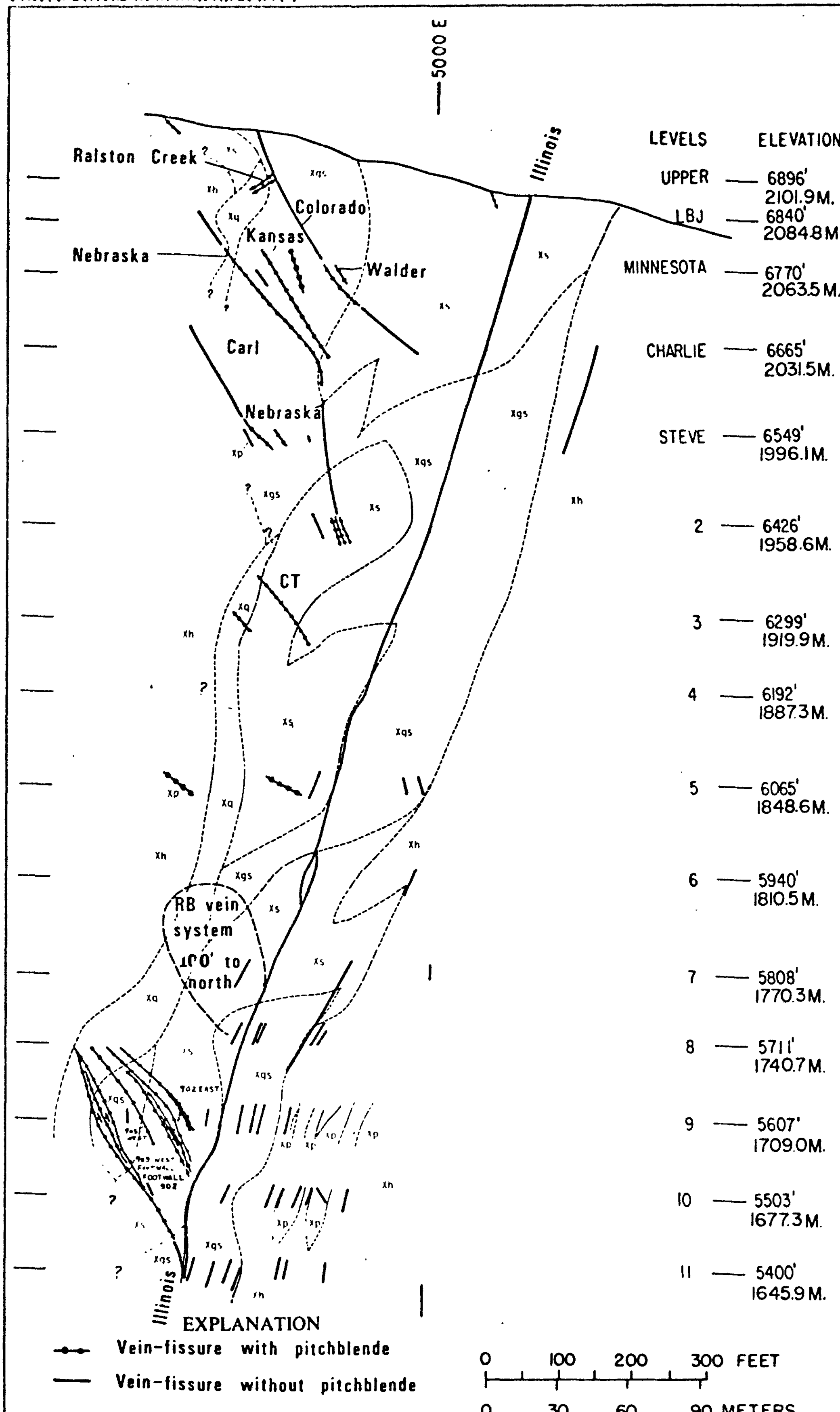


Figure 5. - EAST—WEST CROSS SECTION 4800N

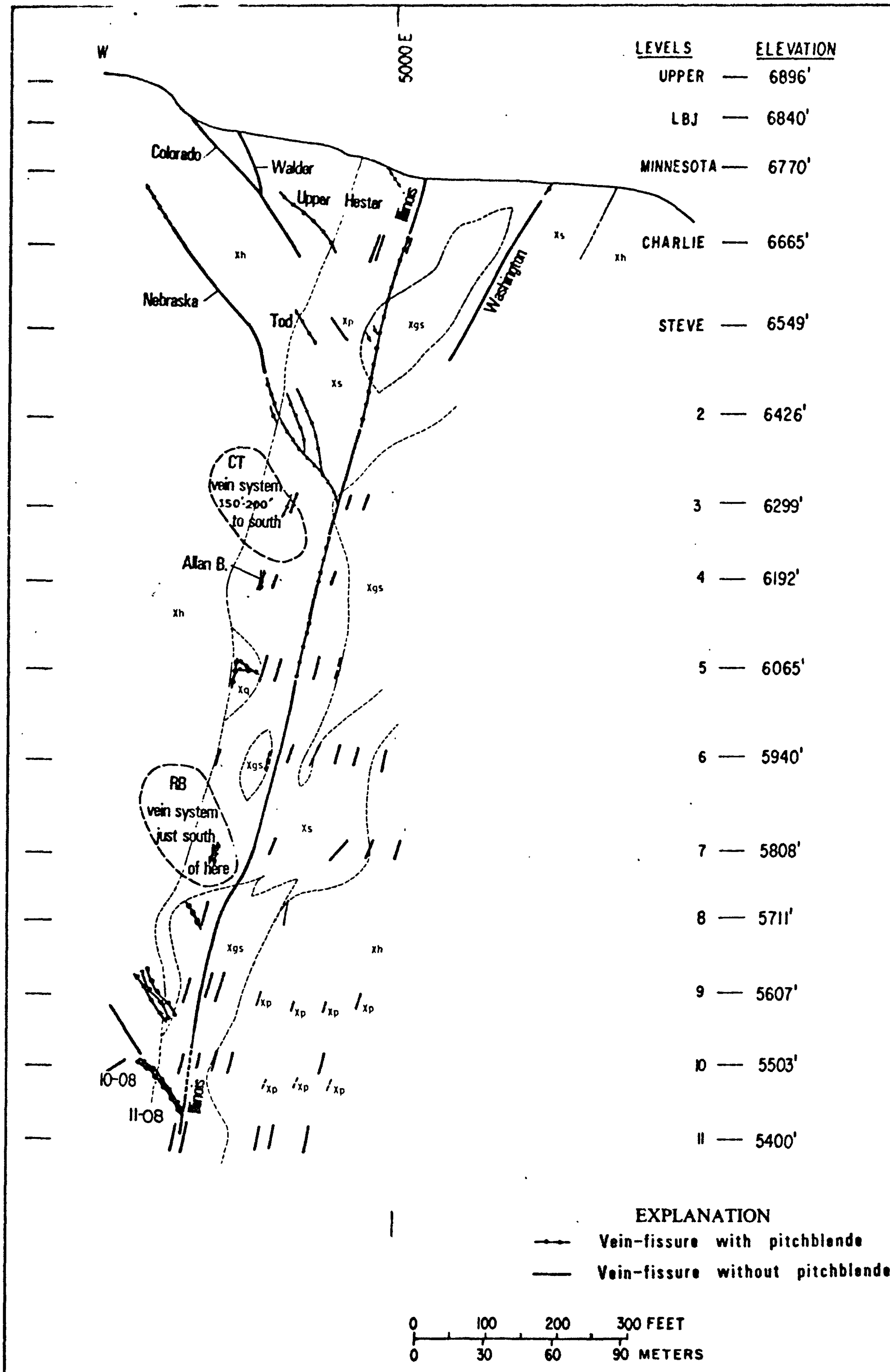


Figure 6. - EAST—WEST CROSS SECTION 5000N

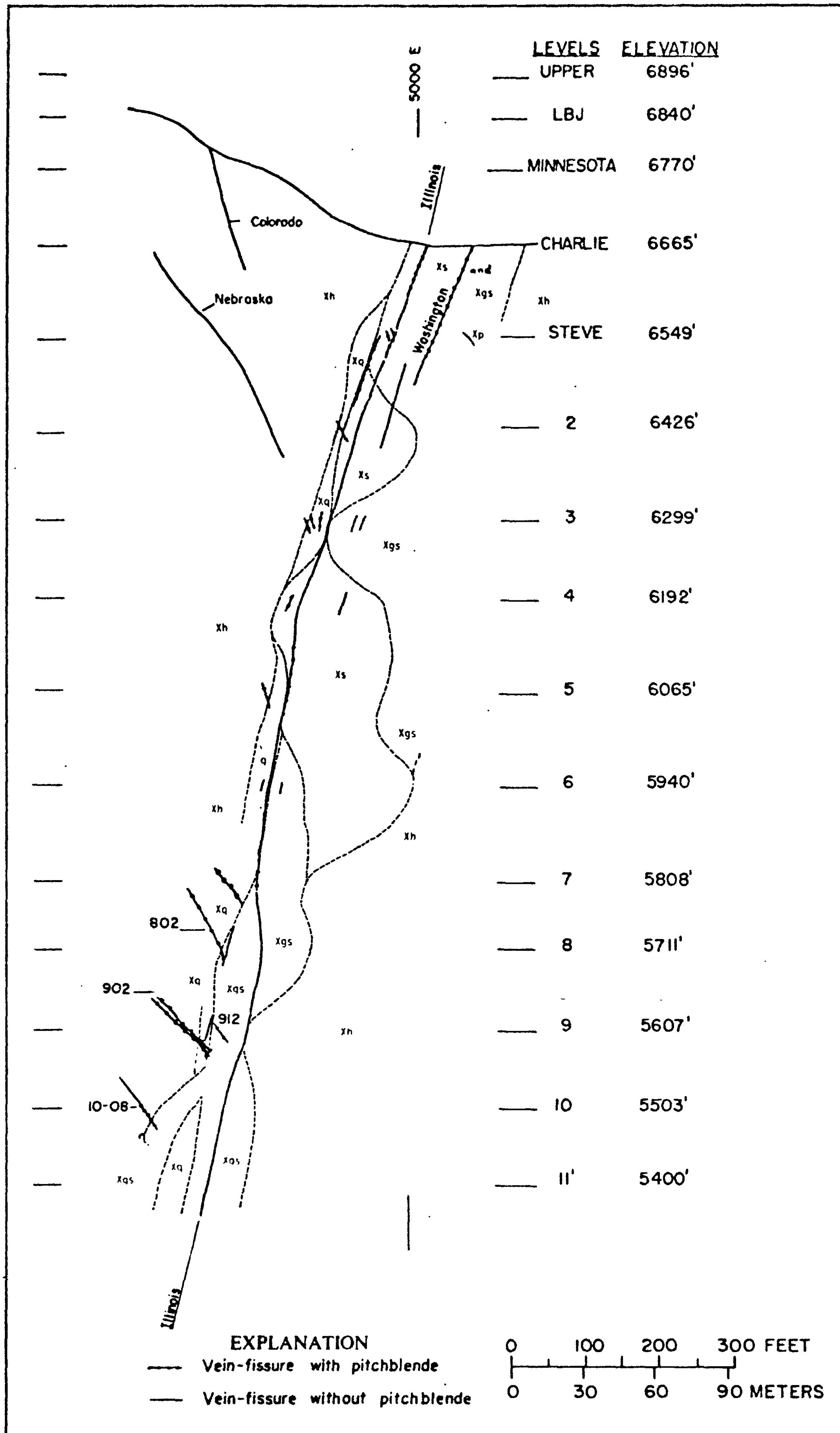
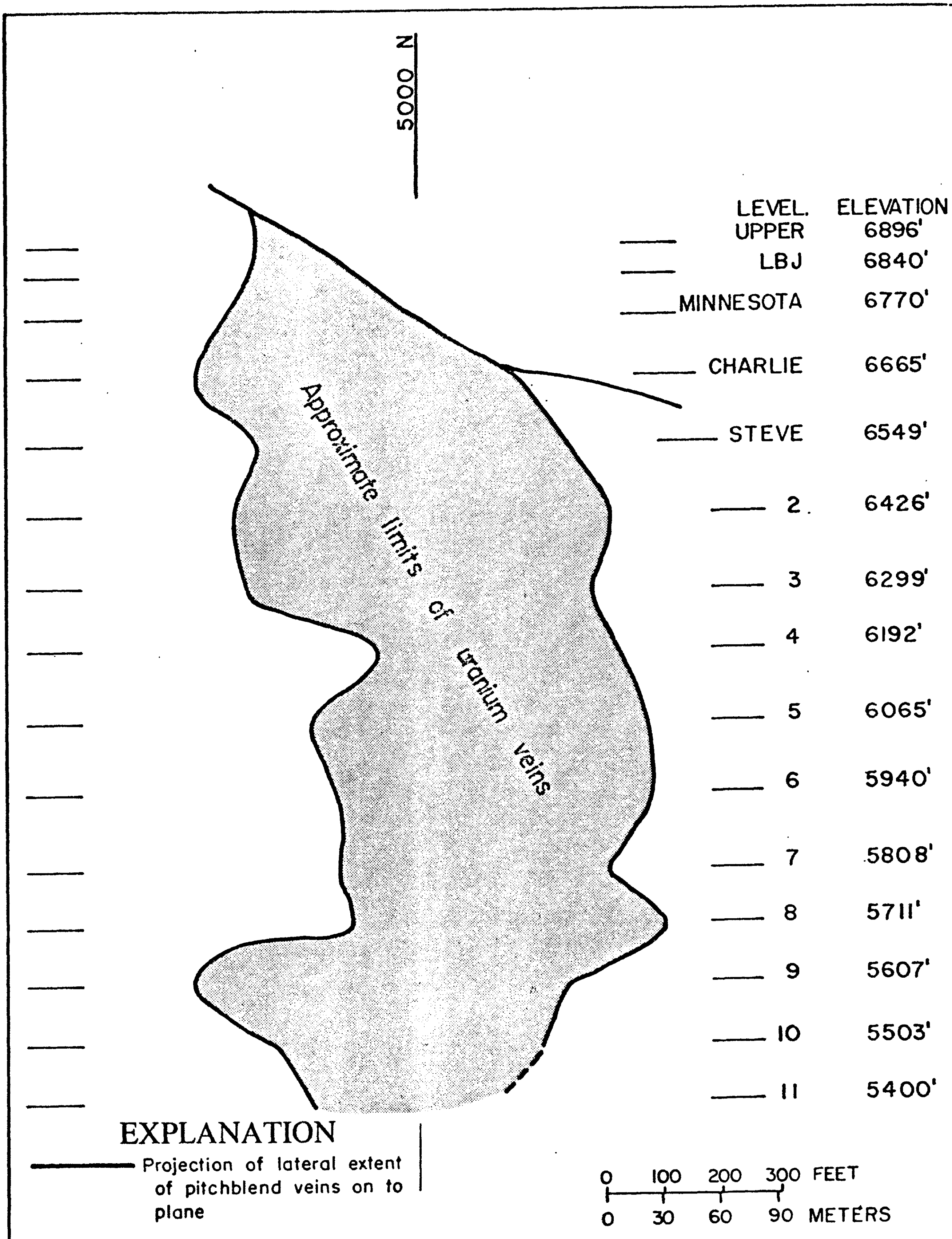


Figure 7. - EAST—WEST CROSS SECTION 5200N



NORTH—SOUTH CROSS SECTION ON 5000E LOOKING WEST

Figure 8. -

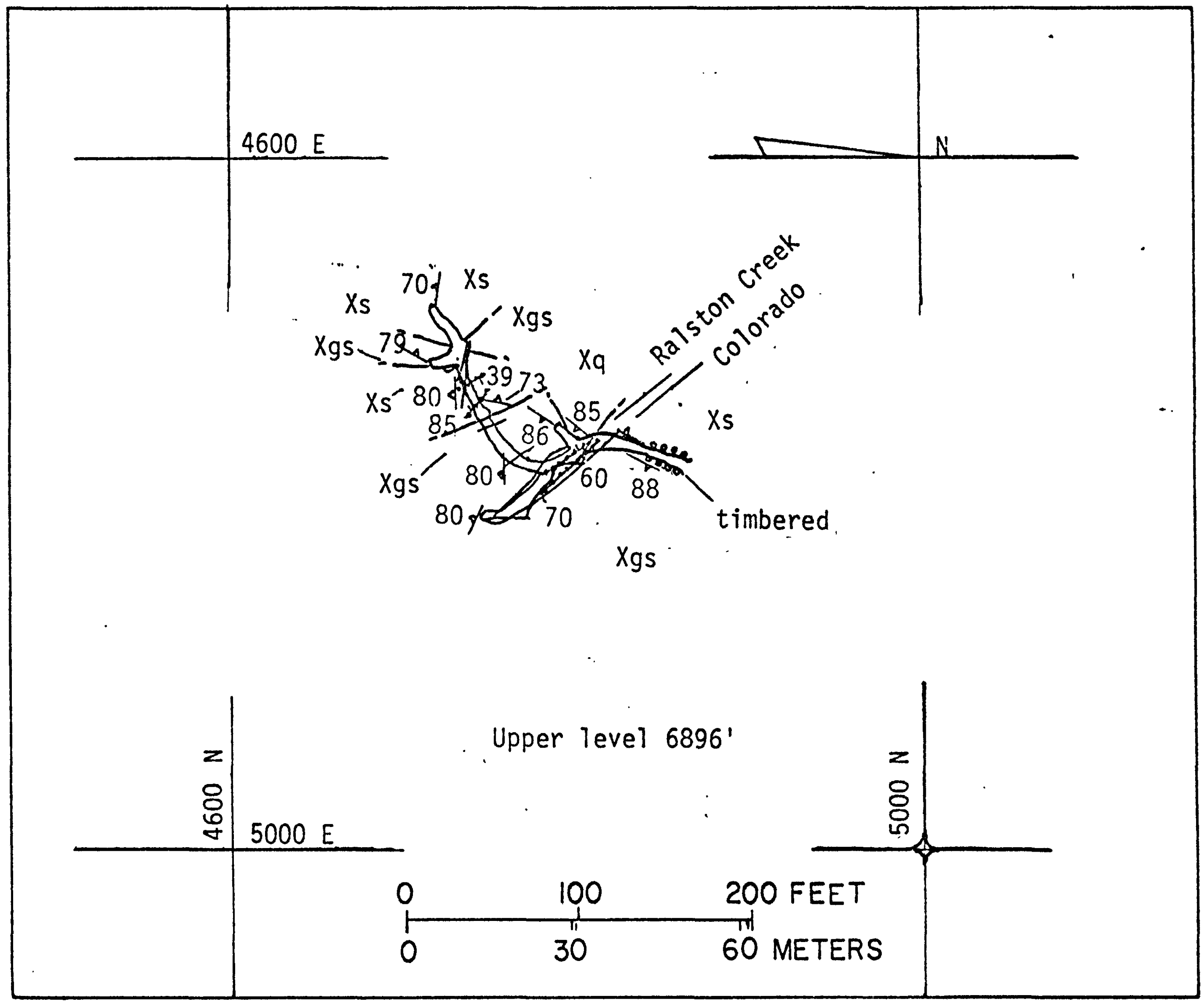


Figure 9a - Plan of underground workings of upper level.

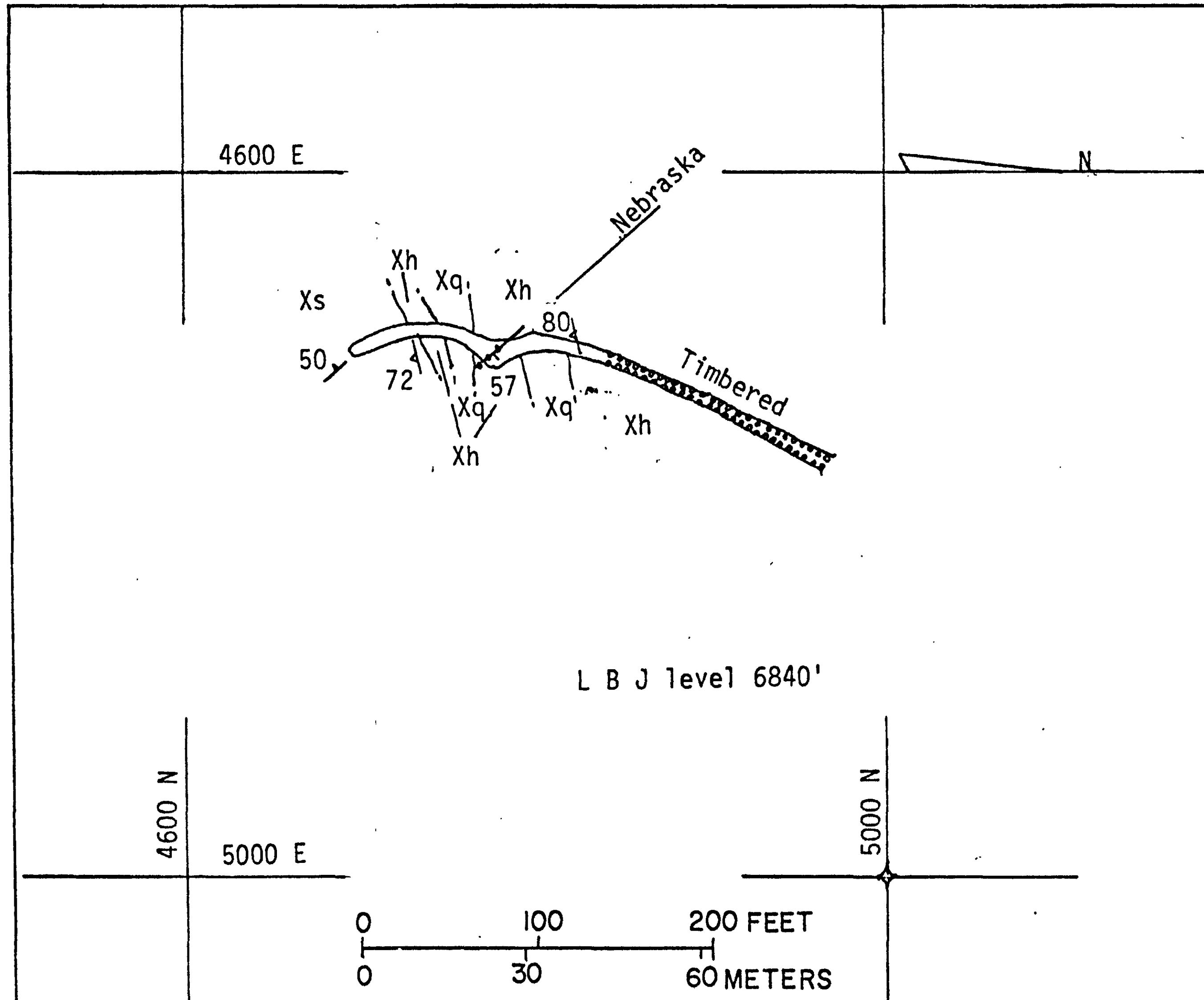


Figure 9b - Plan of underground workings of L B J level.

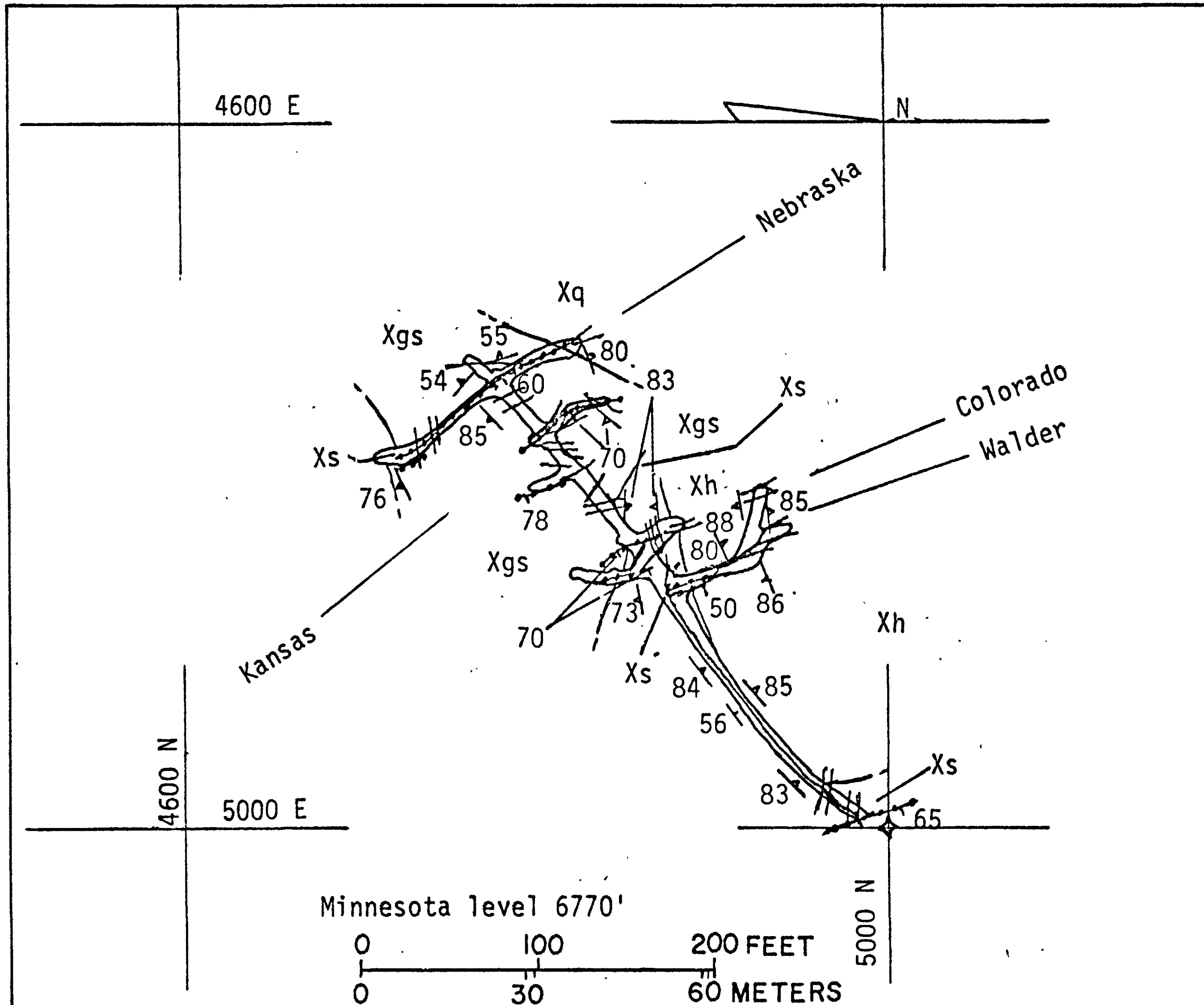


Figure 9c - Plan of underground workings of Minnesota level.

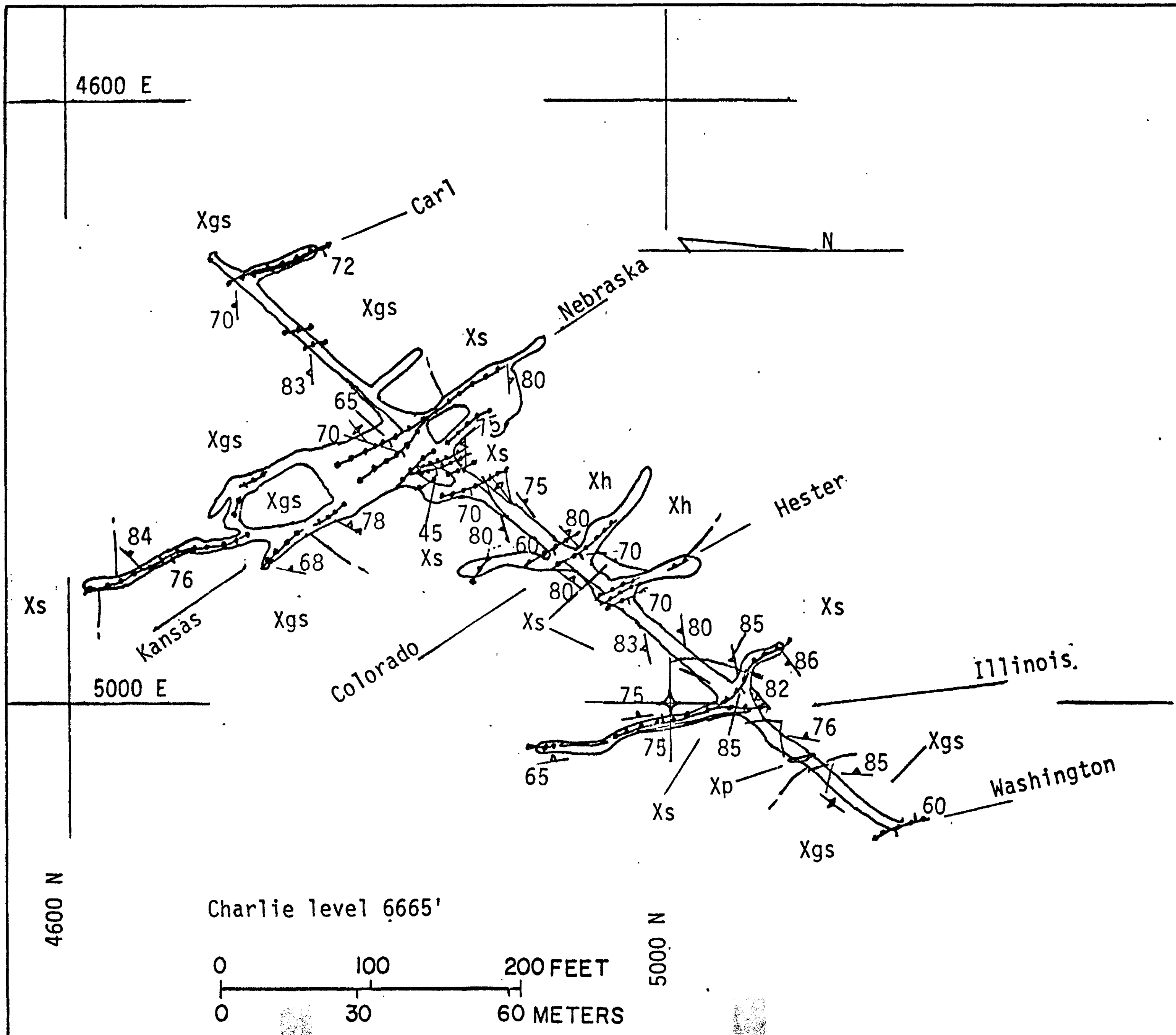


Figure 9d - Plan of underground workings of Charlie level.

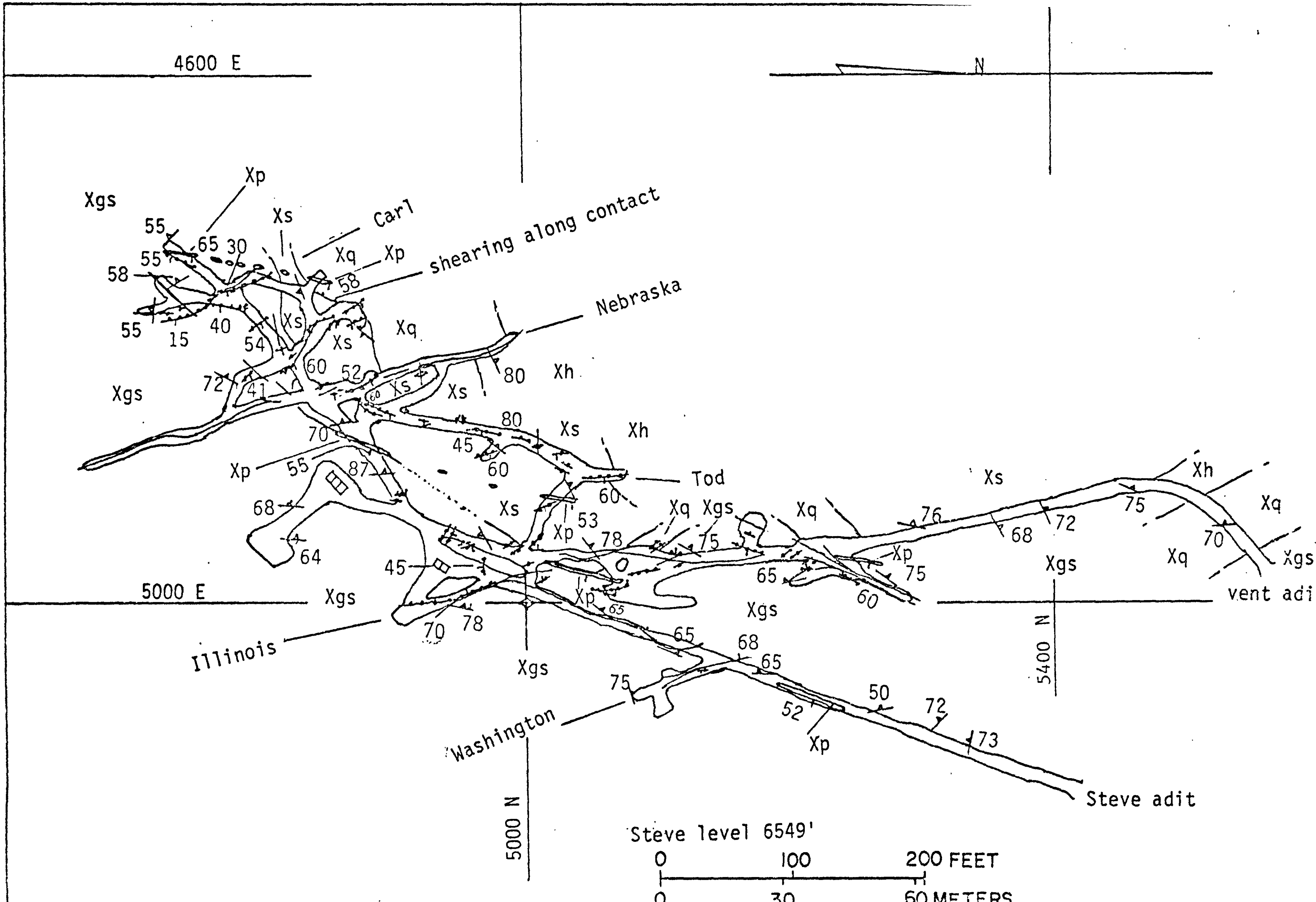


Figure 9e Plan of underground workings of Steve level.

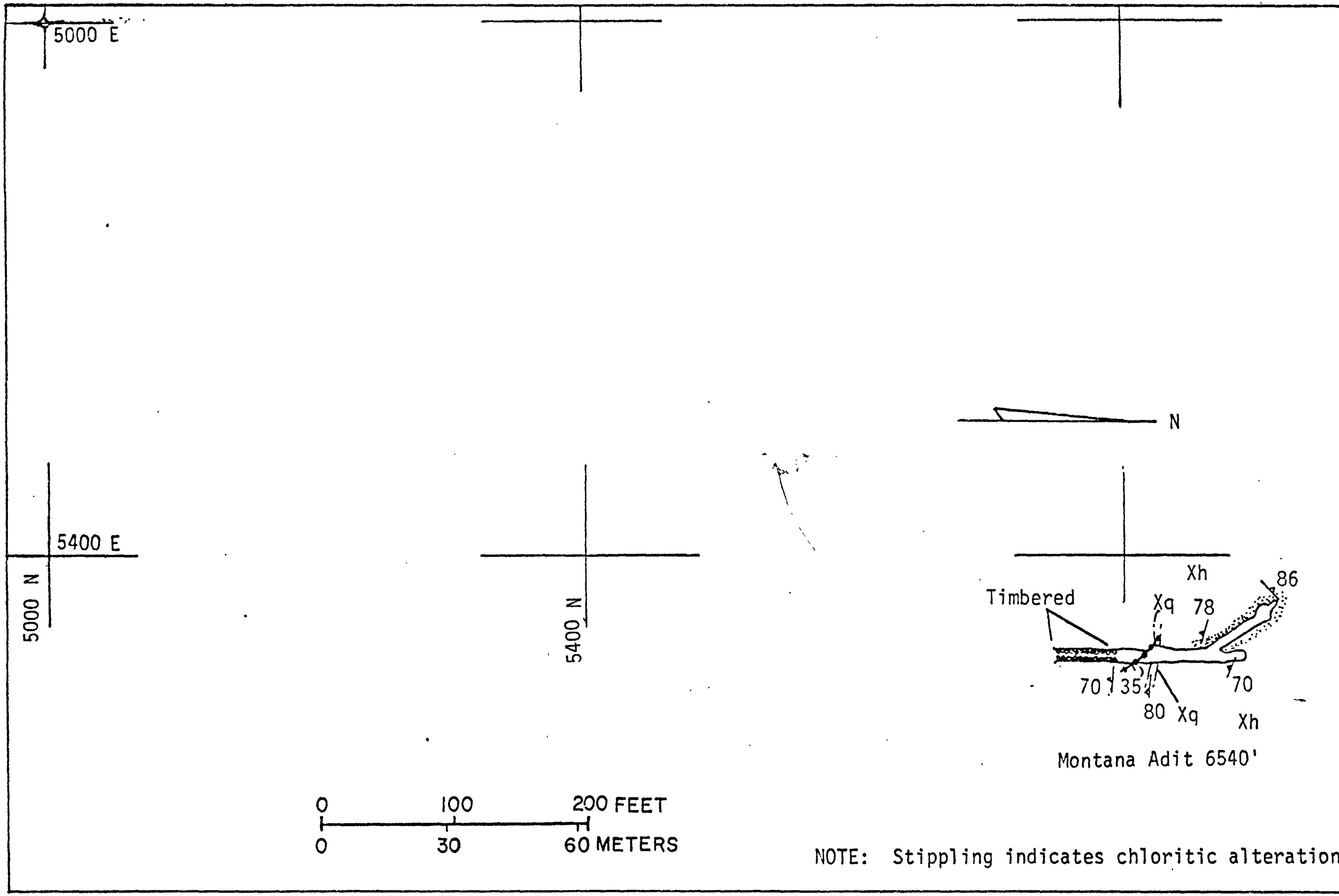


Figure 9f - Plan of underground workings of Montana level.

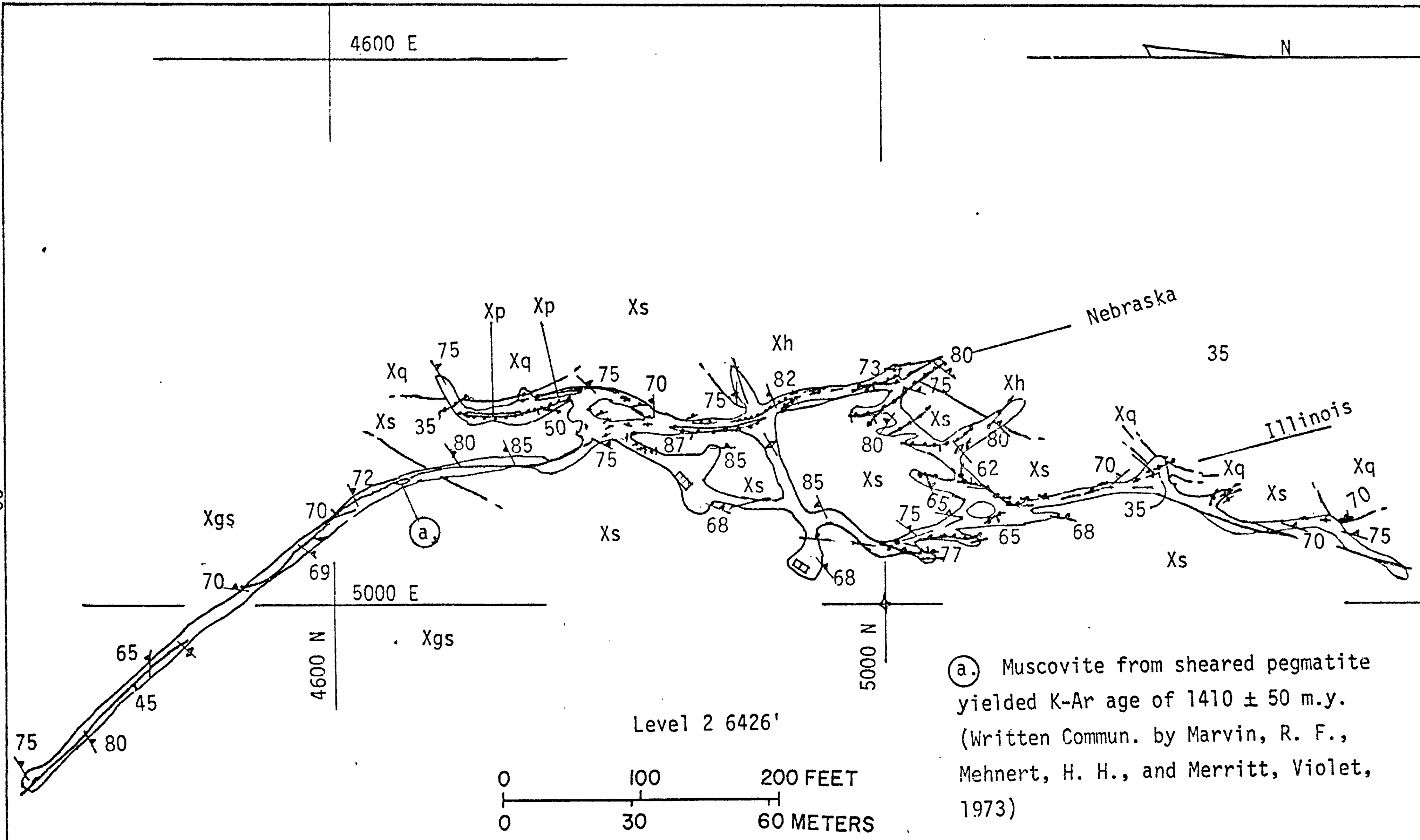


Figure 9g - Plan of underground workings of Level 2.

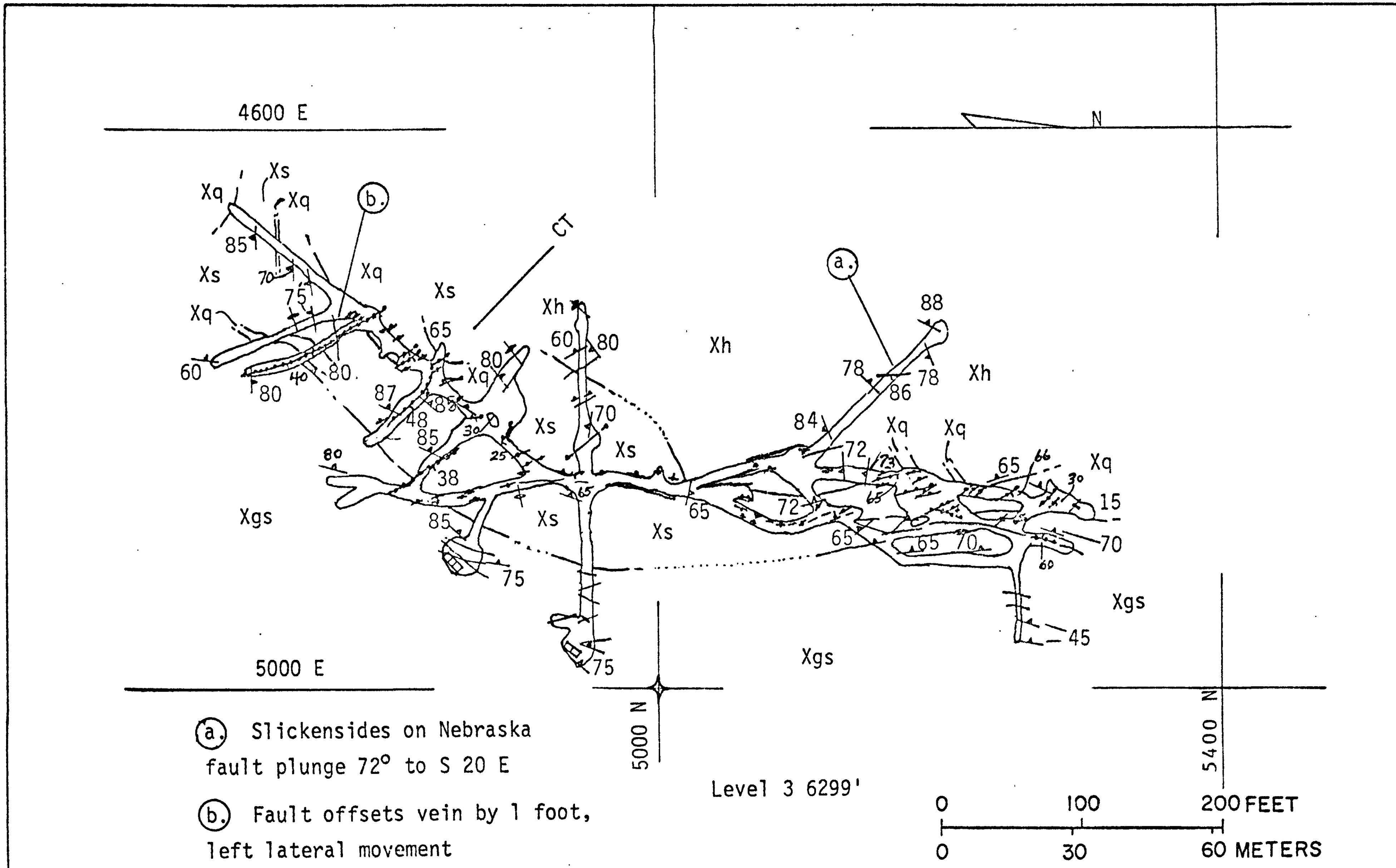


Figure 9h - Plan of underground workings of Level 3.

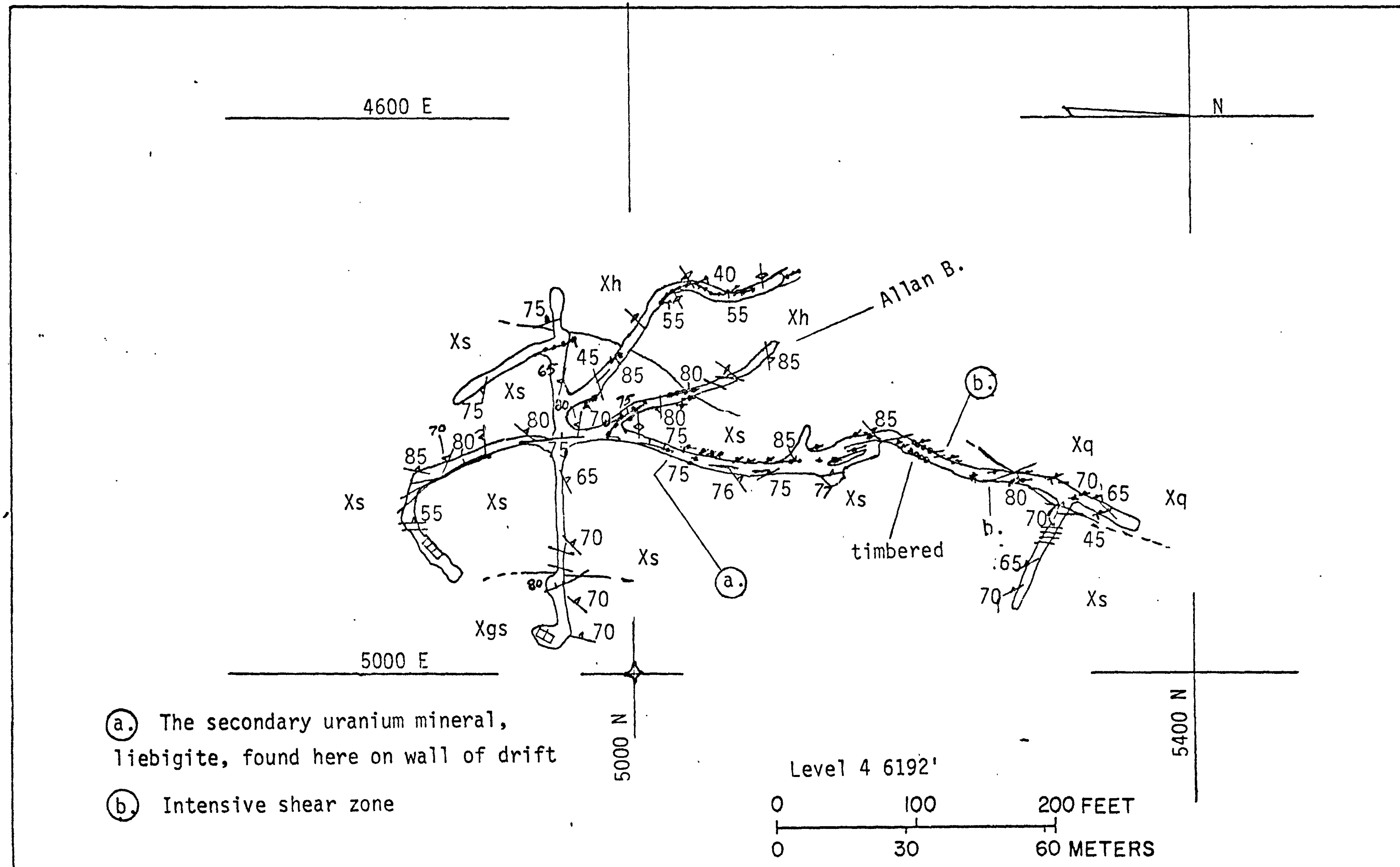


Figure 9j - Plan of underground workings of Level 4.

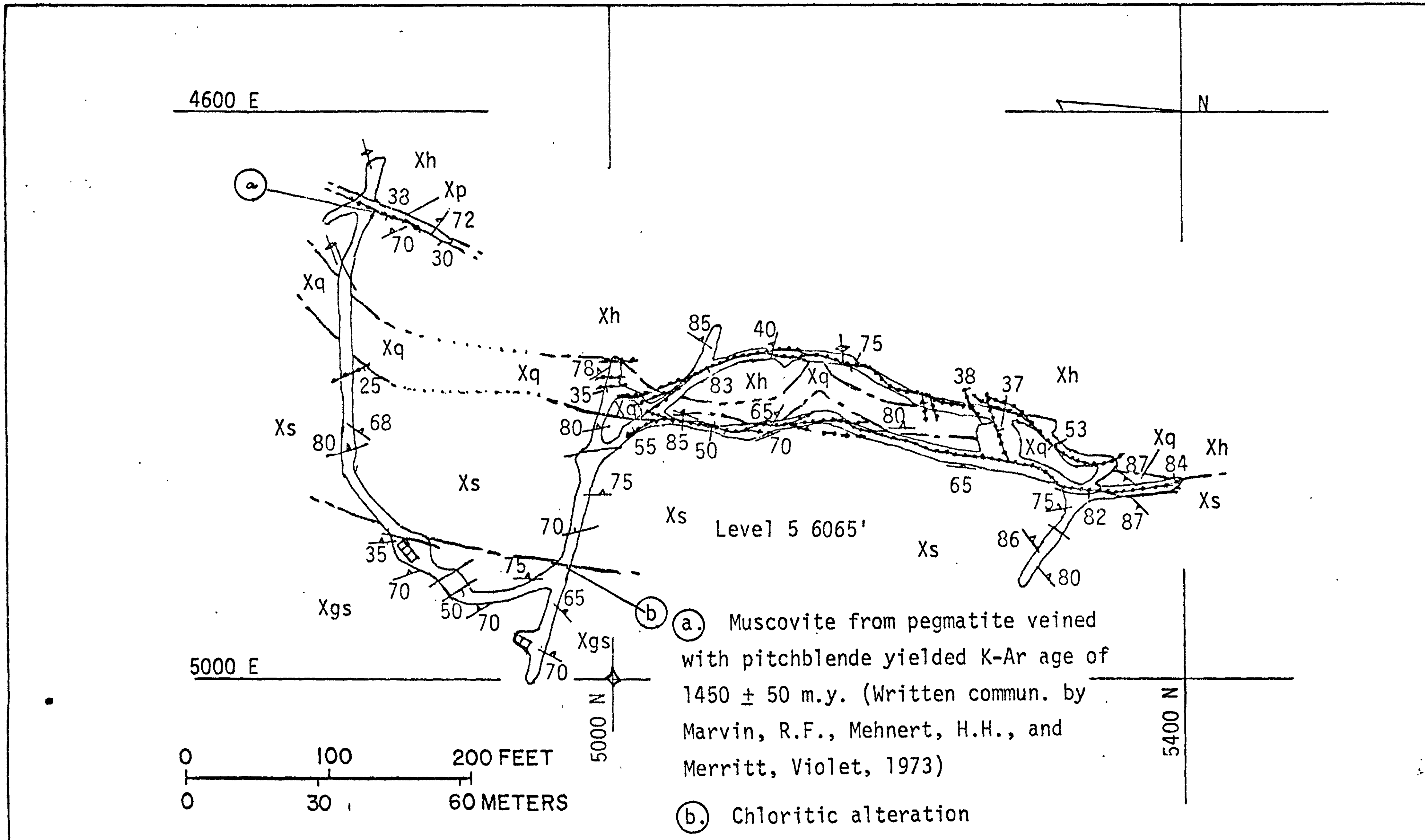


Figure 9k - Plan of underground workings of Level 5.

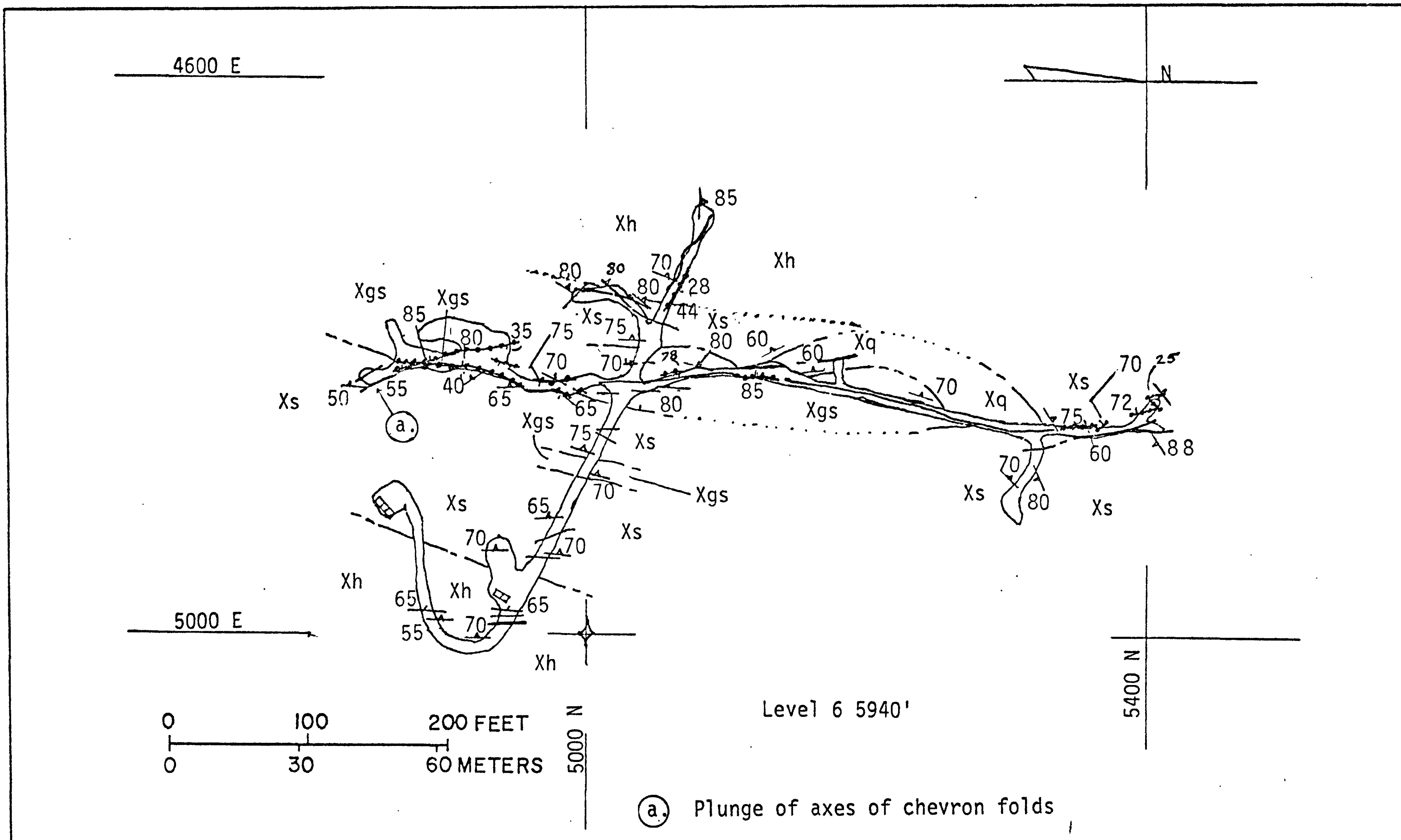


Figure 91 - Plan of underground workings of Level 6.

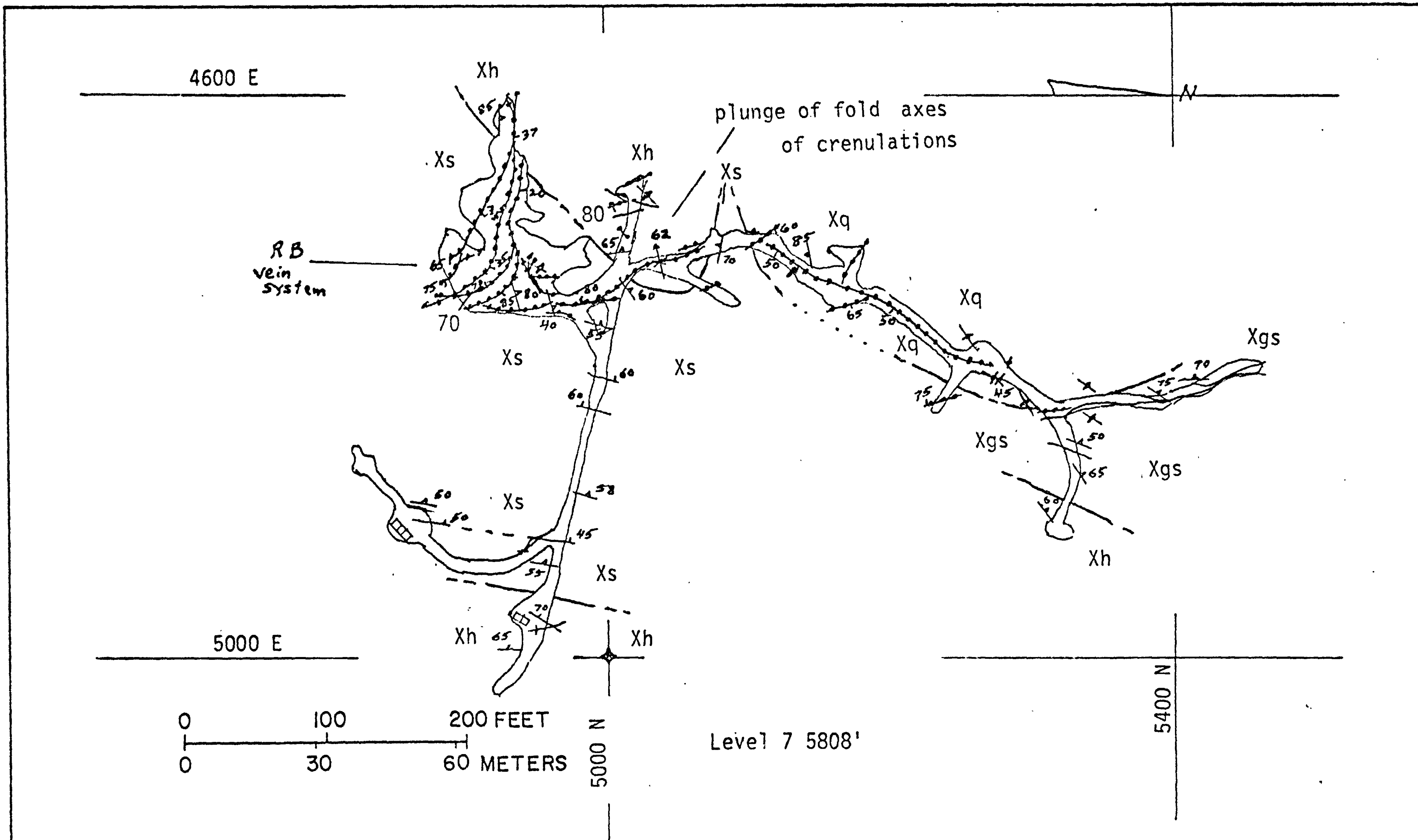


Figure 9m - Plan of underground workings of Level 7.

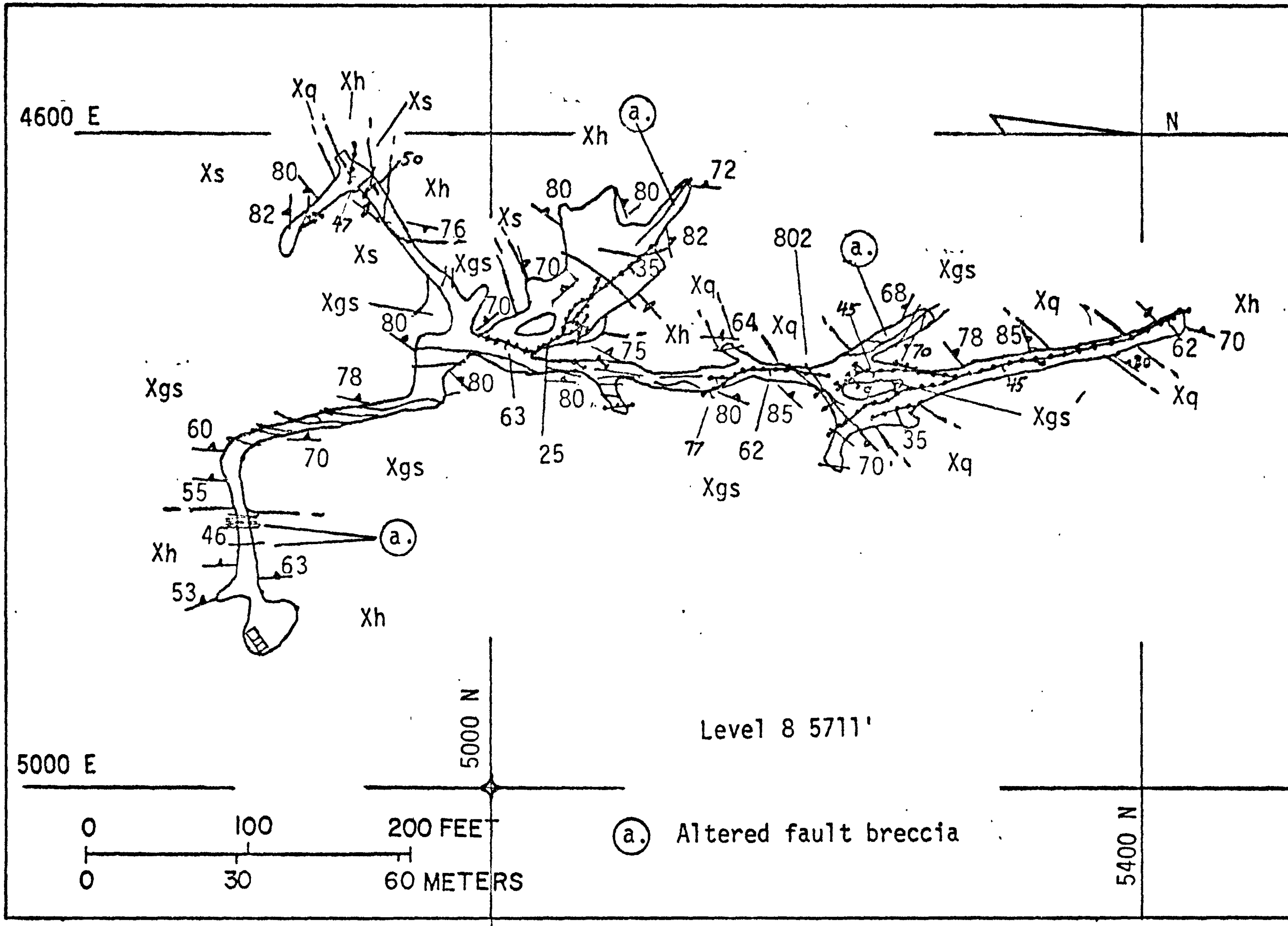
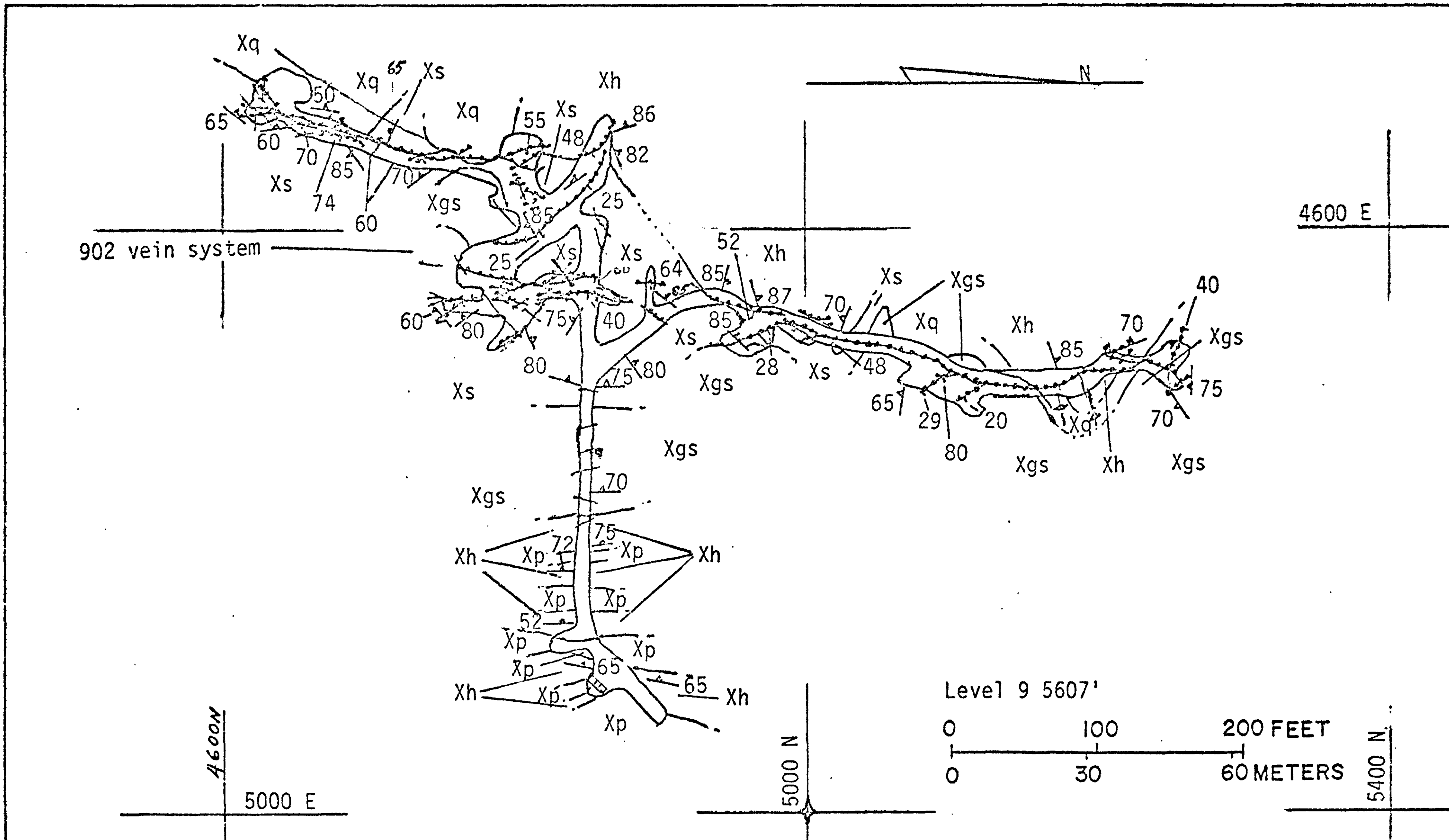


Figure 9n - Plan of underground workings of Level 8.



Fiqure 9o - Plan of underground workings of Level 9.

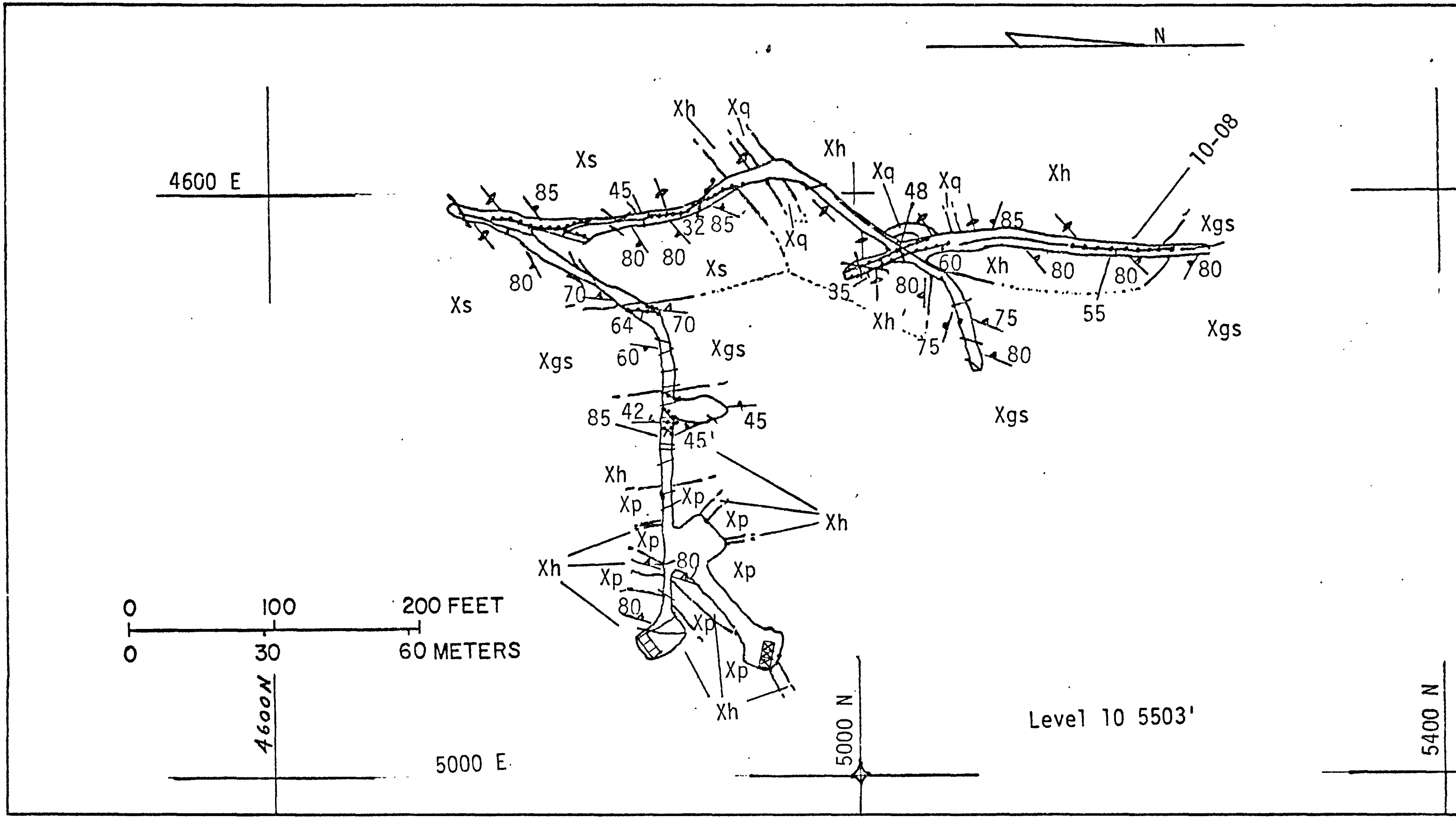


Figure 9p - Plan of underground workings of Level 10.

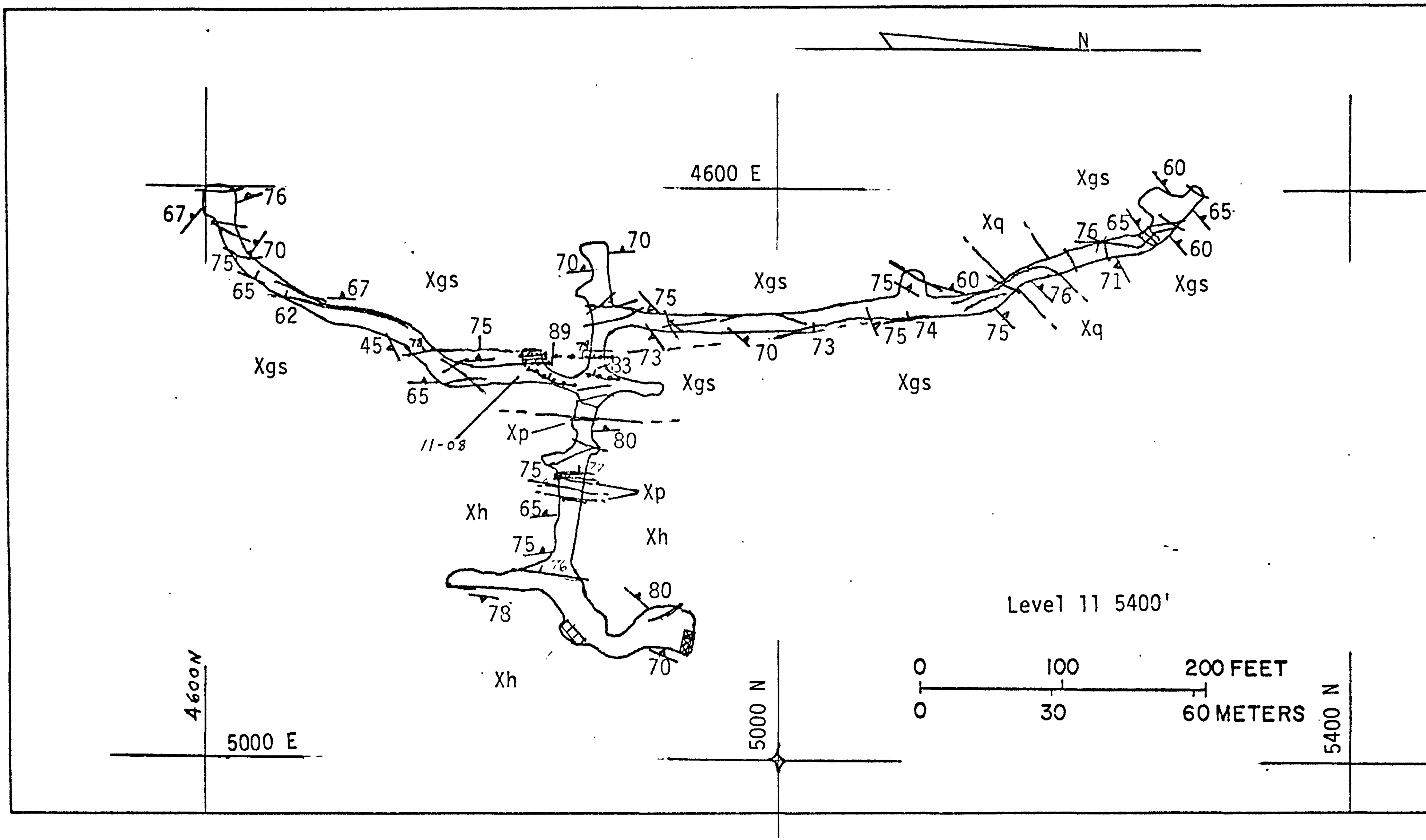


Figure 9q - Plan of underground workings of Level 11.