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Item 81

EXXON MINERALS COMPANY

2425 N. Huachuca Drive
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November 30, 1982

TO: G. WESTRA

FROM: R. CHUCHLA

RE: IMPORTANCE OF CAPROCKS IN DISSEMINATED GOLD DEPOSITS: GENETIC AND EXPLORATION SIGNIFICANCE

GENETIC SIGNIFICANCE

Although certainly critical in the genetic history of some types of ore deposits, I believe the importance of caprocks in both volcanic and sediment-hosted gold deposits has been strongly understated. Caprock, as used here, refers to any relatively impermeable lithology (aquiclude) immediately overlying a permeable lithology (aquifer). It is intentionally distinguished from the "caps" over mineralizing systems formed by the precipitation of secondary minerals (e.g. silica). The following comments are not the result of any sort of comprehensive study but are based on my interpretations of field observations made at the Round Mountain deposit in Nevada. I hasten to add that many of the comments apply equally well to many sediment-hosted disseminated gold deposits (Carlin-type).

Observations

At Round Mountain, ore is hosted in a Tertiary ash flow tuff sequence consisting (from bottom to top) of a lithic tuff, a poorly welded crystal tuff and a densely welded crystal tuff (Figure 1). Two types of ore occur: disseminated mineralization in the poorly welded tuff and stockwork and vein type mineralization. in the densely welded tuff. Drill holes have intersected several high grade, gold-bearing quartz-pyrite-molybdenite-fluorite veins underlying the disseminated ore. A large breccia pipe crosscuts all of the volcanic units but is primarily developed in the densely welded horizon. The pipe is essentially devoid of economic mineralization. Alteration haloes are zoned around the breccia pipe and are characterized from the exterior to the interior of the deposit by the following mineral assemblages: quartz-chlorite, quartz-sericite-chlorite, quartz-sericite-secondary potassium feldspar. In addition, disseminated carbonate and barren carbonate veinlets are present in the poorly welded tuff. A zone of intense argillic alteration is developed in the upper 100' of the poorly welded zone immediately underlying the densely welded zone.

Several features of the Round Mountain deposit deserve emphasis:

1. The presence of a very low permeability densely welded ash flow tuff over a high permeability poorly welded tuff.

2. The occurrence of ore in the densely welded tuff as stockworks and veins with ore in the poorly welded tuff occurring as disseminations.

3. The presence of a breccia pipe at the center of the mineralized system. The breccia pipe was sealed with silica but the surrounding stockwork was not.

4. The presence of feeder veins below the disseminated ore.

Interpretation

The genesis of the Round Mountain deposit is best explained by the following sequence of events (see Fig. 2):

1. Deposition of ash flow tuffs and subsequent compaction and loading to generate a basal poorly welded zone, an intermediate densely welded zone and an overlying poorly welded zone.

2. Ascent and expansion of fluids along a pre-eruption fault or a ring fracture fault which terminates upward at the base of the ash flow tuff sequence. (This is a common situation around calderas where mainstage eruptions cover many of the collapse zone faults).

3. Ponding of fluids near the base of the densely welded tuff. Continued heating and concommitant build-up of fluid pressure causes doming of the area and fluids are forced laterally into the poorly welded ash flow tuff. Several additional comments are warranted here:

   (a) Poorly welded tuffs are usually poor ore hosts. Although porous and generally quite permeable, their permeability is rapidly diminished during alteration. Since reaction with cold, near neutral groundwater is enough to cause rapid devitrification and clay formation, reaction with a hot mineralizing fluid would very quickly occlude fluid pathways. It is thus proposed that very high pressure is necessary to maintain lateral fluid flow in a poorly welded tuff for any significant period of time. Even at shallow levels (epithermal environment), very high fluid pressure could be developed in a reservoir below a caprock of high tensile strength. Maximum fluid pressure within the reservoir would be limited by tensile strength of the caprock, plus lithostatic pressure.

   (b) The change from poor to dense welding (or high to low porosity/permeability) in ash flow tuffs is transitional (Figure 3). At Round Mountain the poorly welded tuff grades upward to the densely welded tuff over an interval of 50 to 100'. This transitional welding zone coincides with a barren interval between the stockwork ore and the disseminated ore. The transitional zone was probably not permeable enough to host disseminated ore or competent enough to sustain fracturing. The presence of a barren zone between two ore horizons in this type of rock should be expected.

4. A volcanic and/or seismic event followed by tectonic readjustment within the caldera causes faulting and rupturing of the caprock. Fluids flash boil, breccias and stockworks are formed in the densely welded tuff, a zone of strong argillic alteration develops over the disseminated ore zone

and peripheral to the stockworks, and gold is deposited. The sudden decompression and drop in temperature of the fluid causes rapid precipitation of silica, especially in the breccia matrix, and resealing of the system. It should be emphasized here that the entire process of volatile release, breccia formation, gold deposition and silica precipitation are probably catastrophic and short-lived. The main ingredient of the above process, which enhances the formation of very large stockworks and breccias, is the sudden release of the very large volume of fluids. This contrasts strongly with other described styles of breccia formation where a relatively small volume of fluid in a structure flash boils and generates a small breccia which is subsequently infiltrated by circulating water and sealed over an extended period of time.

It is interesting to note that the stockwork at Round Mountain which contains the ore in the densely welded tuff consists of fractures and joints with limonites after sulfides but very little gangue. The stockwork does not appear to have been sealed and refractured. It may represent a single pulse of mineralization. The breccia, on the other hand, appears to have been sealed with silica and comminuted igneous rocks but is not mineralized. One gets the impression that almost all of the silica was dumped at the focus of decompression (breccia) but that gold was carried out and deposited in the fracture envelope surrounding the breccia pipe.

Implied but not directly stated in the previous discussion is one other very important function of caprocks: they are heat barriers. A single intrusive associated with a typical geothermal system will probably cool in less than 10,000 years due to rapid heat loss through convection. Much longer cooling times result if the top of the system is impermeable because convective heat loss operates only until the heat from the intrusion is trapped against the caprock. Subsequently, very slow cooling occurs by conductive heat loss through the impermeable cap. Long-lived, "closed" geothermal systems certainly have the best chances of spawning economic ore deposits. Single pass, "open" systems are not likely to produce ore deposits.

The salient feature of the above model is the volcanic stratigraphy; an impermeable caprock (densely welded tuff) over a moderately permeable lithology (poorly welded tuff) is perhaps critical to the formation of a large disseminated gold deposit. I feel that had the volcanic sequence at Round Mountain been reversed (poorly welded tuff overlying densely welded tuff), disseminated mineralization would not have formed and the potential for very extensive stockwork mineralization in the densely welded tuff would have been greatly reduced.

Finally, I suggest that similar lithological control might have been exerted on Carlin-type gold mineralization. Carlin and Alligator Ridge are two good examples where gold mineralization occurs at a lithologic contact characterized by a strong permeability contrast (Carlin at the Roberts Mountain/Popovich contact and Alligator Ridge at the Guilmette/Pilot contact).

EXPLORATION SIGNIFICANCE

To satisfy the main features of the genetic model presented above, the following criteria must be satisfied:

1. Presence of a caprock (aquiclude) underlain by a potential fluid reservoir (aquifer). For example, in volcanic terrain, this might take the form of a basalt, andesite or rhyolite flow over tuffaceous moat sediments, a rhyolite

flow over the poorly welded zone of an underlying ash flow tuff or, as at Round Mountain, a densely welded zone of an ash flow overlying a poorly welded basal zone. Ash flow tuffs, in general, should be excellent hosts for disseminated gold mineralization due to the dramatic porosity and permeability contrasts across zones exhibiting differing degrees of welding. Figure 3 illustrates porosity profiles across three different ash flow tuffs. Note that, by itself, only the Battleship Rock ash flow tuff would be a good host for disseminated gold mineralization since a densely welded zone of low porosity overlies a poorly welded zone of very high porosity. The poorly welded zones of the Bishop tuff and the Te Toki Point tuff would be good hosts only if they were overlain by an impermeable rock.

It should be pointed out that the position of maximum welding is related to the amount of loading and to the amount of heat conservation (insulation). Where the former effect is dominant a basal vitrophyre will form (Figure 3a,b). Where the latter effect is dominant, the densely welded zone will form well above the base of the ash flow tuff (Figure 3c). Thus, without field inspection it is very difficult to predict the zone of maximum welding.

A barren zone at the transition between zones of dense and poor welding should be expected. Permeability in this zone is too low to permit disseminated mineralization, and the rock is not competent enough to sustain fracturing (and host stockwork mineralization). The thickness of the permeable reservoir may be important. A very thick permeable reservoir may distribute fluids into an excessive volume of rock leading to subeconomic mineralization.

2. Presence of hydrothermal breccias in competent, impermeable rocks (densely welded tuffs, flows, etc.). Based on the genetic model hydrothermal breccias must be generated as fluid is episodically and very violently released from a high pressure fluid reservoir. The size of the breccia masses and the degree of comminution should be good qualitative guides to the ultimate size of the mineralized system.

3. Presence of domal structures. The genetic model predicts that domes would be favorable areas for the localization of high pressure fluid reservoirs and, in fact, should often result from pressurization of the reservoir. Failure of the caprock would be expected over the apex of the dome where tensional strain resulting from bending stress is greatest. Pressure release from the apex of the dome would focus energy over a discrete area to maximize brecciation and stockwork formation.

This suggests that resurgent domes within calderas are prime sites for disseminated gold mineralization.

Richard

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sfl

cc: T.D. Irwin

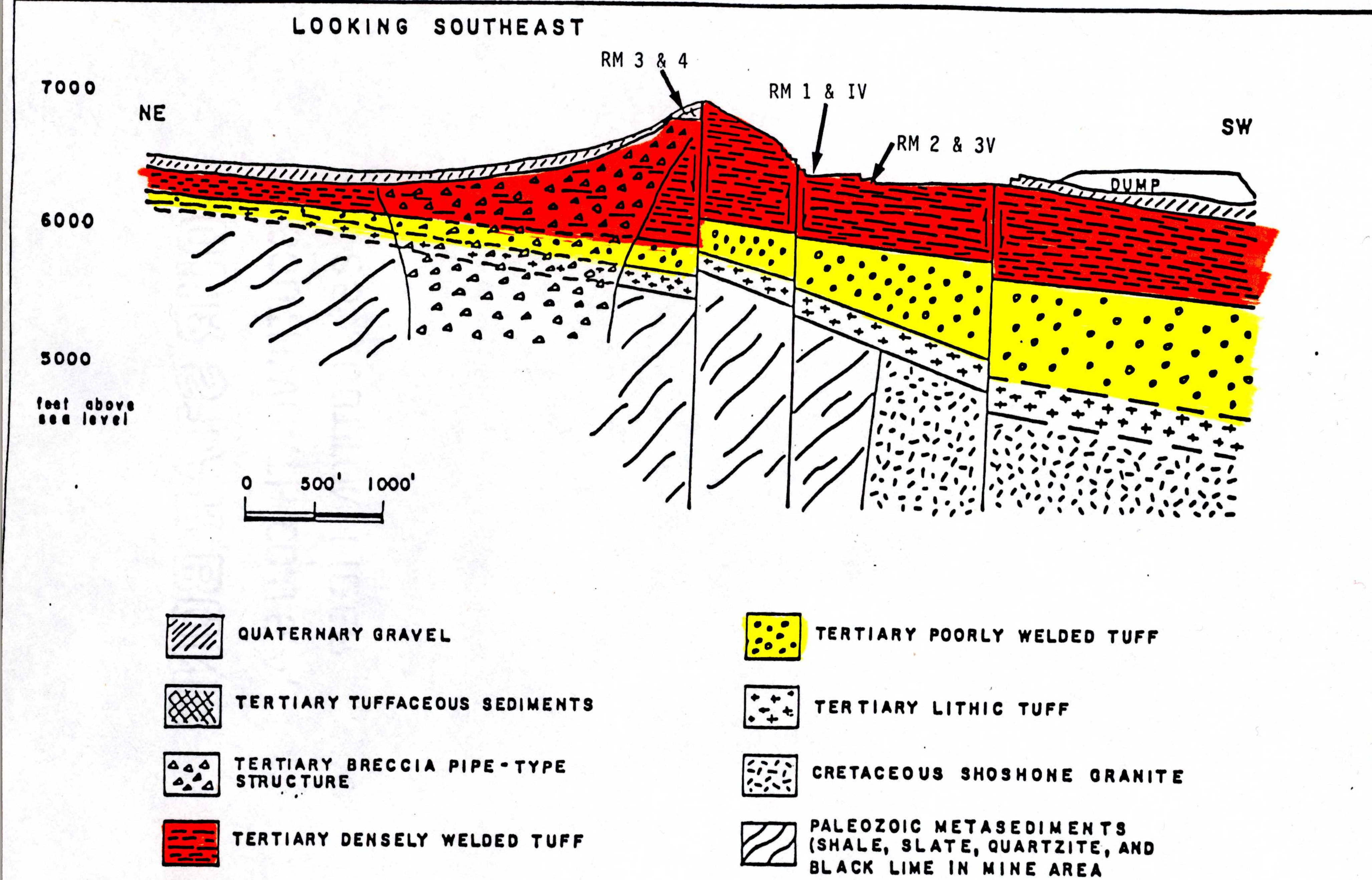

Figure 1. Cross section; Round Mountain deposit, NV.

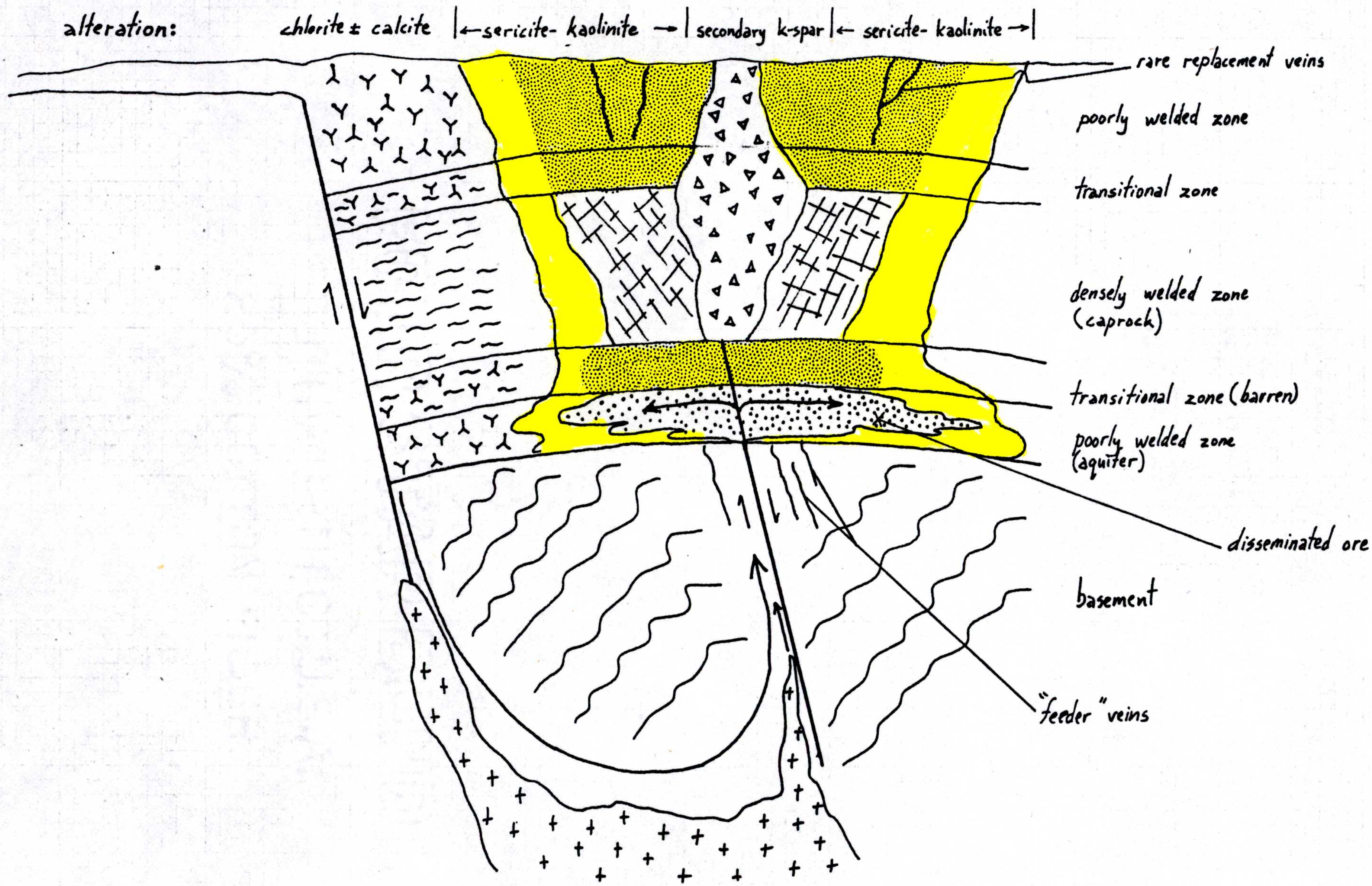

Figure 2. Conceptual model of a Round Mountain-type gold deposit. Dense stippling indicates zones of intense argillic alteration. Yellow coloring outlines the argillic halo.

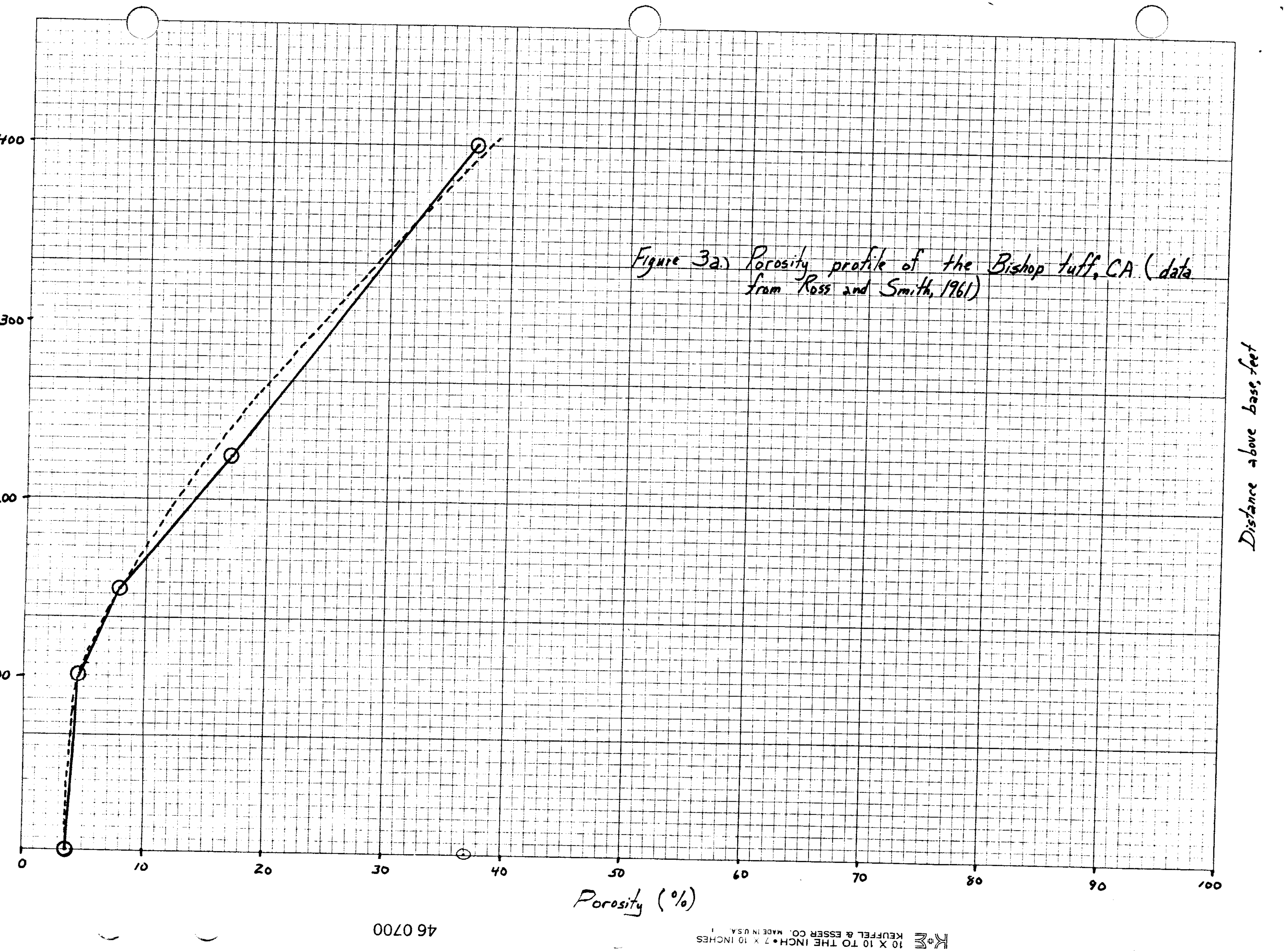

Figure 3a.) Porosity profile of the Bishop tuff, CA (data from Ross and Smith, 1961)

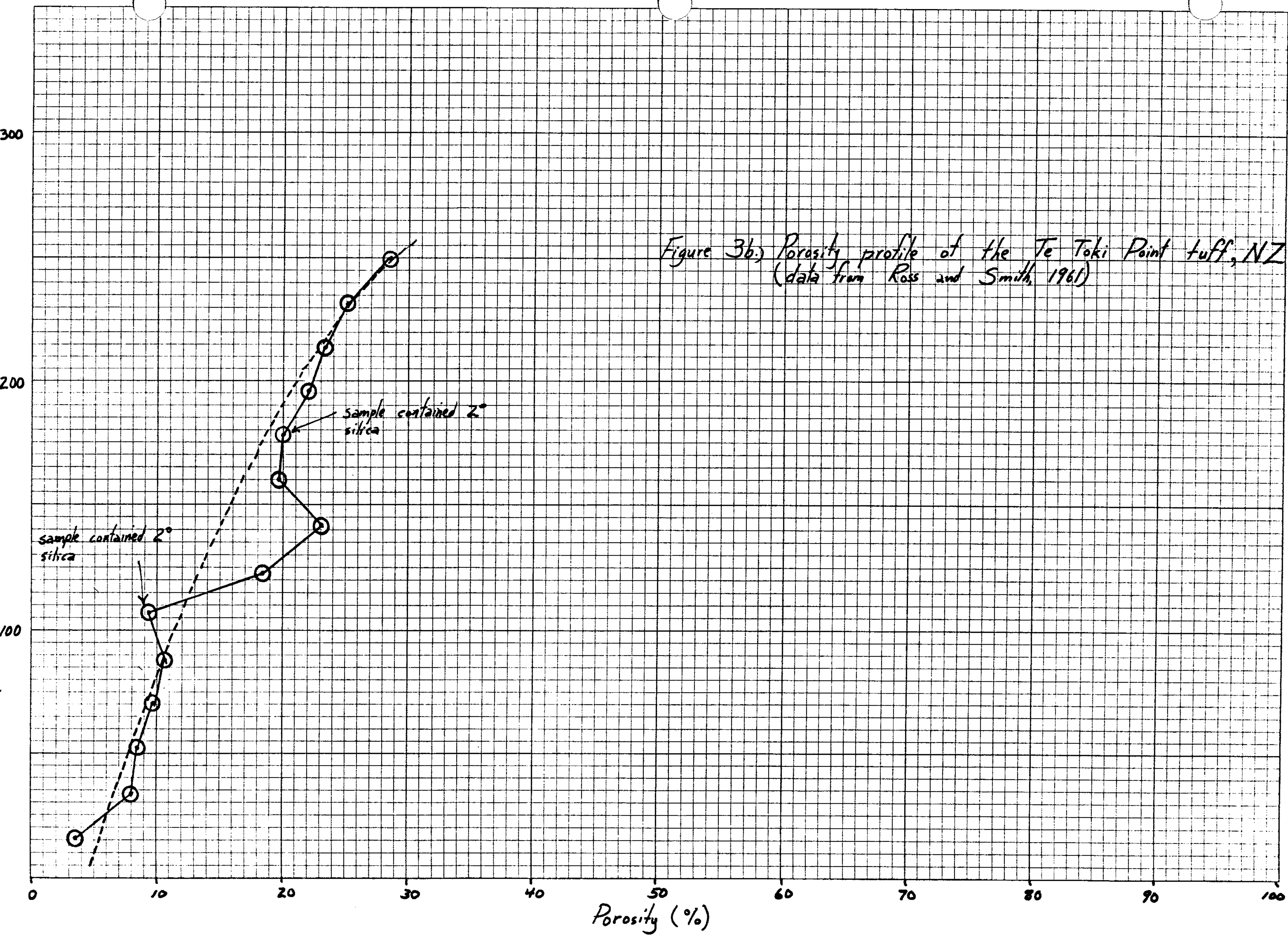

Figure 3b.) Porosity profile of the Te Toki Point tuff, NZ
(data from Ross and Smith, 1961)
sample contained 2° silica
sample contained 2° silica
Distance above base, feet
300
200
100
0
10
20
30
40
50
60
70
80
90
100
Porosity (%)

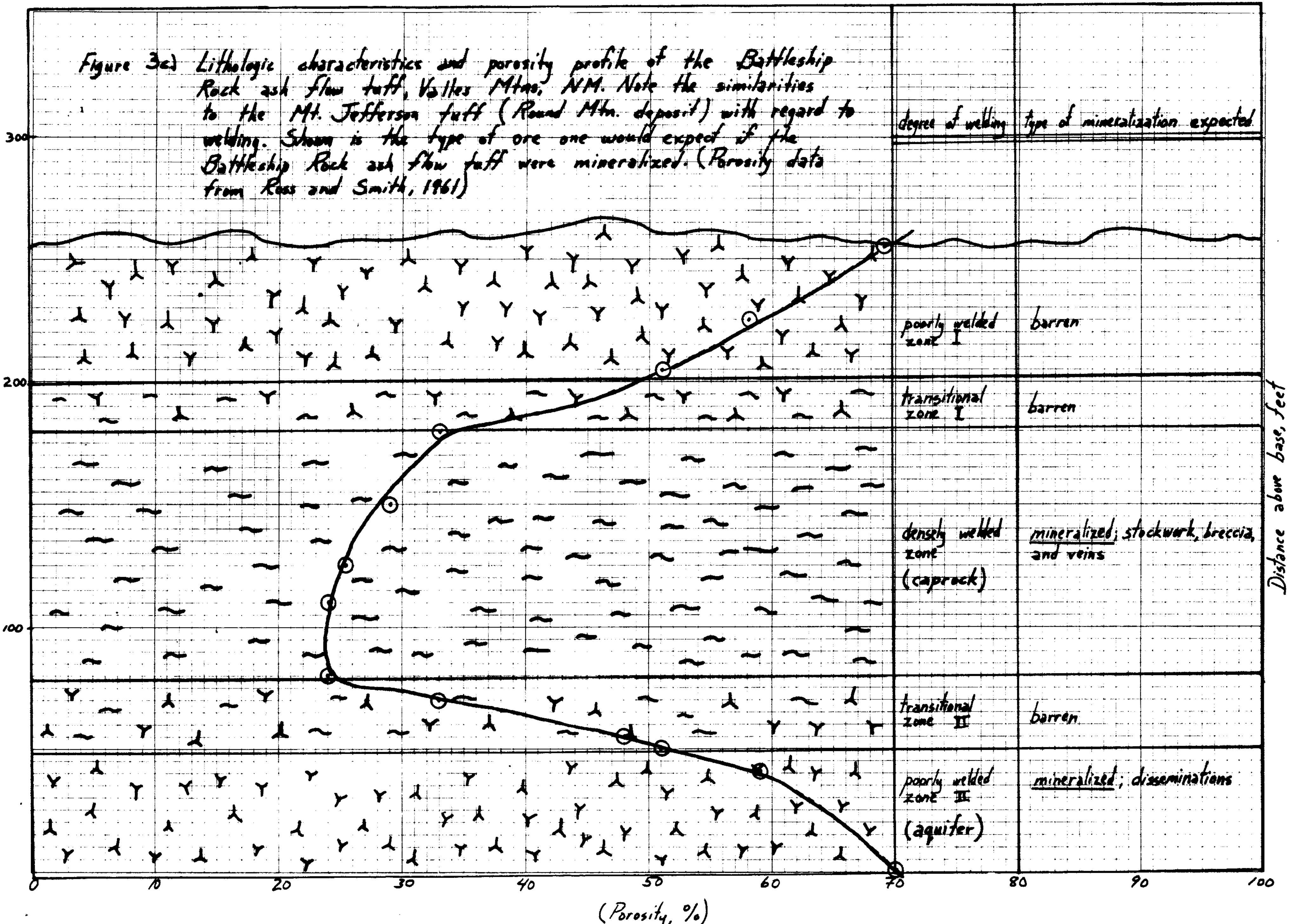

Figure 3c) Lithologic characteristics and porosity profile of the Battleship Rock ash flow tuff, Valles Mtns, N.M. Note the similarities to the Mt. Jefferson tuff (Round Mtn. deposit) with regard to welding. Shown is the type of ore one would expect if the Battleship Rock ash flow tuff were mineralized. (Porosity data from Ross and Smith, 1961)