Boletín de la Sociedad Geológica del Perú v. 95 (2003) p. 33-38

ASH-FLOW SHEETS OF EARLY MIOCENE AND EARLY PLIOCENE AGE ARE PRESENT IN THE CASTILLO DE CALLALLI, AREQUIPA DEPARTMENT, SOUTHERN PERÚ

Donald C. NOBLE [1], Pedro A. NAVARRO [2], Luis QUISPESIVANA [2], Lisa PETERS [3] & Edwin H. MCKEE [4]

[1] *3450 Rolling Ridge Road, Reno, NV 89506 USA. Email: dcn@kori.reno.nv.us*
[2] *Instituto Geológico Minero y Metalúrgico, Av. Canadá 1470, San Borja, Lima 41, Perú. Email: peanavarro@hotmail.com; qpsivana@ingemmet.com.pe*
[3] *New Mexico Geochronology Research Laboratory, New Mexico Bureau of Mines and Mineral Resources, New Mexico Tech, 801 Leroy Place, Socorro, NM 87801, USA. Email: lisa@nmt.edu*
[4] *U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA, 94025 USA. Email: mckee@mojave.wr.usgs.gov*

ABSTRACT

Two ash-flow sheets of markedly different age and petrography are exposed in the Castillo de Callalli. The lower, phenocryst-rich ash-flow sheet of low-silica rhyolite has a K-Ar age of 20.7±0.6 Ma. The overlying ash-flow sheet is composed of sanidine-bearing high-silica rhyolite. An $^{40}Ar/^{39}Ar$ age of 4.72±0.02 Ma and petrographic characteristics show that the unit is almost certainly the lower ash-flow sheet of the Cailloma Tuff, which in adjacent quadrangles has been mapped variously as Fm. Sencca, Fm. Garza, Fm. Yauri, and Ignimbrita Acopata.

Key words: ***Cailloma Tuff, Castillo de Callalli, ash-flow sheet, isotopic dating***

RESUMEN

Dos secuencias de flujos de ceniza marcadamente diferentes en petrografía y edad, están expuestas en el Castillo de Callalli. El inferior es rico en fenocristales que corresponde a una riolita de baja sílice, mediante K-Ar presenta una edad de 20.7±0.6 Ma. Los flujos de ceniza superior son riolita de alta sílice y con presencia de sanidina y con una edad de $^{40}Ar/^{39}Ar$ de 4.72±0.02 Ma. Cuyas características petrográficas muestran que esta unidad corresponde a la unidad de flujo de ceniza inferior de las Tobas Cailloma, las cuales en los cuadrángulos adyacentes fueron cartografiadas de modo diverso como: Fm. Sencca, Fm. Garza, Fm. Yauri e Ignimbrita Acopata.

Palabras claves: ***Toba Cailloma, Castillo de Callalli, capa de flujos de ceniza, datación isotópica***

INTRODUCTION

The Castillo de Callalli is a well-known landmark overlooking the pueblo of Callalli near the intersection of the road from Arequipa to Cusco with the Río Colca (Fig. 1). The hill exposes about 400 meters of densely welded to non-welded ash-flow tuff of silicic composition that Ellison and De la Cruz (1985) assigned to the "Fm. Pichu". Readily visible layering shows that the section consists of a number of discrete ash flows (Fig. 2). The sequence has generally been considered to comprise a single stratigraphic unit, which Ellison and De la Cruz (1985) assigned to the "Fm. Picchu". Instead, isotopic dating and phenocryst mineralogy show that the Castillo de Callalli consists of at least two different ash-flow sheets of early Miocene and early Pliocene age separated in time by sixteen million years.

LOWER PART OF SECTION

The lower part of the Callalli section consists of densely welded, devitrified ash-flow tuff with well-developed vertical columnar jointing. The tuff contains abundant phenocrysts of plagioclase, quartz, hornblende and biotite accompanied by a moderate percentage of lithic fragments. Composition is probably low-silica rhyolite.
A K-Ar age determination has been obtained on a sample from the lower part of the unit collected from a road cut at the point where the road to Cailloma separates from the present main road to Cusco. Phenocrystic hornblende from the sample yielded a K-Ar age of 20.7±0.6 (1 sigma) Ma (K_2O=0.734 wt. %; $^{40}Ar^*=2.196\times10^{-11}$ moles/gm; $^{40}Ar^*/^{40}Ar^{tot}$=21.3 %). This age is corroborated by the age of 17.11±0.10 Ma of the high-silica rhyolite domes of the Río

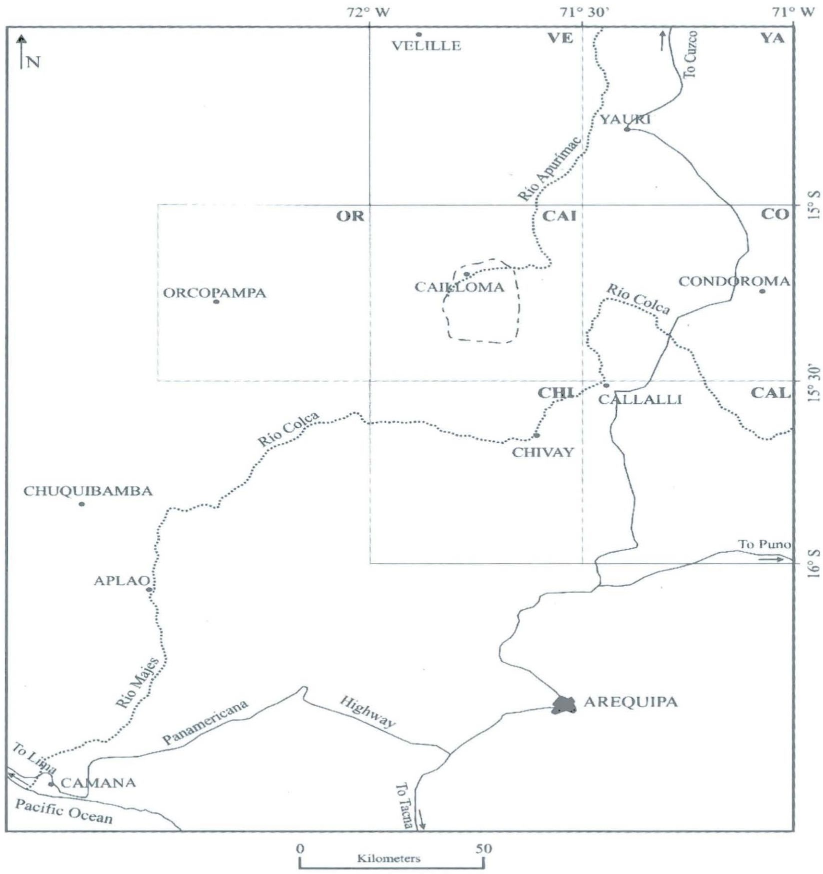


Fig. 1: Map showing location of Castillo de Callalli. 1:100,000-scale quadrangles are abbreviated as follows: VE, Vellille; YA, Yauri; OR, Orcopampa; CAI, Cailloma; CO, Condoroma; CHI, Chivay; CAL, Callalli.

Fig. 2: Photograph towards the south showing the Castillo de Callalli. The pueblo of Callalli is in the lower left.

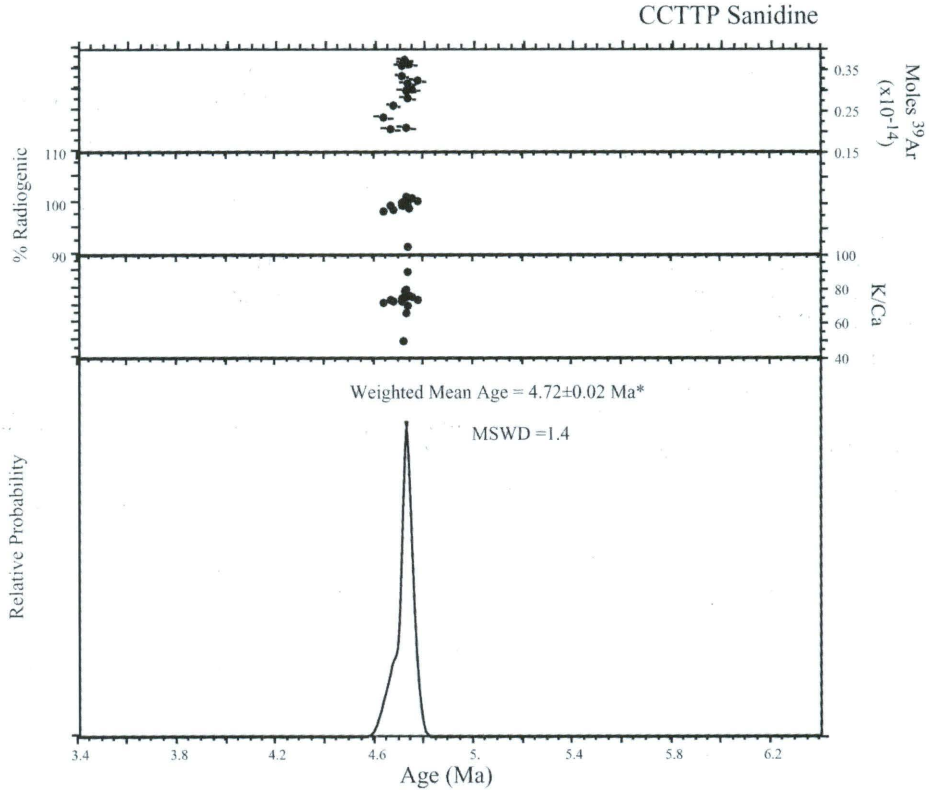


Fig. 3: Age probability distribution plot for sanidine CCTTP from the lower ash-flow sheet of the Cailloma Tuff exposed in the upper part of the Castillo de Callalli.

Chalhuanca dome field about 10 km to the southeast, which overlie the lower ash-flow sheet (Noble et al., 2002b).

UPPER PART OF SECTION

Tuff in the upper part of the section is composed of partly welded, vapor-phase crystallized tuff with the physical characteristics of the distal part of an outflow sheet. The tuff differs markedly from that exposed in the lower part of the section in that it contains phenocrysts of quartz, sanidine and sodic plagioclase and is probably of high-silica rhyolite composition. Lithic fragments are rare.

A very precise and accurate $^{40}Ar/^{39}Ar$ age determination of 4.72±0.02 Ma has been obtained on phenocrystic sanidine separated from a specimen (CCTTP) collected from the uppermost part of the section at UTM coordinates 0238300E, 8281300N. The determination is the weighted average of fifteen laser-fusion single-crystal analyses with a MSWD of 1.4. The results of the analyses are graphically presented in Figure 3 and the data given in the appendix.

DISCUSSION AND CONCLUSIONS

The K-Ar age obtained on tuff from the lower part of the section is consistent with the possibility that the tuff is part of the Manto Tuff, which is well developed to the west in the Chila Cordillera and north and west of the Orcopampa Valley (Swanson et al., 1993; Swanson, 1998). However, the precision of the K-Ar age is not sufficient to demonstrate or disprove this possible correlation. The age determination places an upper limit on the age of andesite lavas and other rocks that underlie the unit, which are lithologically similar to the andesite lavas and breccias of the early Miocene Santa Rosa Volcanics in the Orcopampa quadrangle (Swanson et al., 1993; Swanson, 1998).

The petrographically different unit of ash-flow comprising the upper part of the Castillo de Callalli is almost fifteen million years younger than that comprising the base. Clearly, two different ash-flow sheets are present.

The phenocryst mineralogy of the upper upper ash-flow unit exposed at the Castillo de Callalli is similar to that of the Cailloma Tuff, erupted from the Cailloma caldera to the north (Noble, 1979; Dávila, 1981). The Cailloma Tuff, consists of at least three distinct ash-flow sheets erupted at about 2.5, 3.4 and 4.7 Ma (Noble et al., 2002a). These ash-flow sheets have been mapped as "Fm. Sencca" in the Orcopampa and Cailloma quadrangles (Caldas & La Torre, 1973; Dávila et al., 1988; Swanson, 1998). In the Velille and Yauri quadrangles proximal portions of the Cailloma Tuff have been mapped as "Fm. Garza" whereas distal portions have been mapped as "Fm. Yauri" (De la Cruz and La Torre, 1995; De la Cruz, 1995). In the Condoroma and Callalli quadrangles, the Cailloma Tuff has been mapped mainly as "Ignimbrítica Acopata" by Hawkins and de la Cruz (1985) and Ellison and de la Cruz (1985). Figure 4 shows the known distribution of the Cailloma Tuff, based on the distributions of the several units on the above maps and on our field observations.

The $^{40}Ar/^{39}Ar$ age of 4.72±0.02 Ma on tuff that forms the upper part of the Castillo de Callalli is slightly older than the K-Ar age of 4.3±0.16 Ma (K_2O=9.94 wt. %; $^{40}Ar^*=6.1915\times10^{-11}$ moles/gm; $^{40}Ar^*/^{40}Ar^{tot}$=47.1 %)

obtained on the lower part of the Cailloma Tuff northeast of the Cailloma caldera (CAI-012; 15°03.3'S, 71°40.1'W) and the age of 4.4±0.1 Ma (K_2O=11.00 wt. %; $^{40}Ar^{*}=6.9010\times10^{-11}$ moles/gm; $^{40}Ar^{*}/^{40}Ar^{tot}=46.3$ %) from an outcrop between Yauri and the Tintaya mine (YAURI-1). The differences, however, are probably within the limits of analytical uncertainty of the K-Ar determinations, particularly when the systematically younger ages obtained in K-Ar dating of certain sanidines are taken into account (Hausback et al., 1990).

We have not yet had the opportunity to study the Castillo de Callalli in detail, and the possibility exists that additional ash-flow sheets are present within the central part of the section. Units that might be present include a sanidine-bearing ash-flow sheet dated at *ca.* 16 Ma exposed about 55 kilometers to the west on the north side of Río Colca. Another possibility is a unit of plagioclase and biotite rich ash-flow tuff, mapped as "Ignimbrita Confital", that outcrops about 17 km south of Callalli on the road to Arequipa.

In conclusion, isotopic dating confirms that two ash-flow sheets of markedly different age and petrographic characteristics are exposed in the lower and uppermost parts of the Castillo de Callalli. The present study emphasizes the importance of determining the phenocryst mineralogy of units of ash-flow tuff in the field, and shows that care must be taken in the recognition, definition and naming of cartographic units.

A

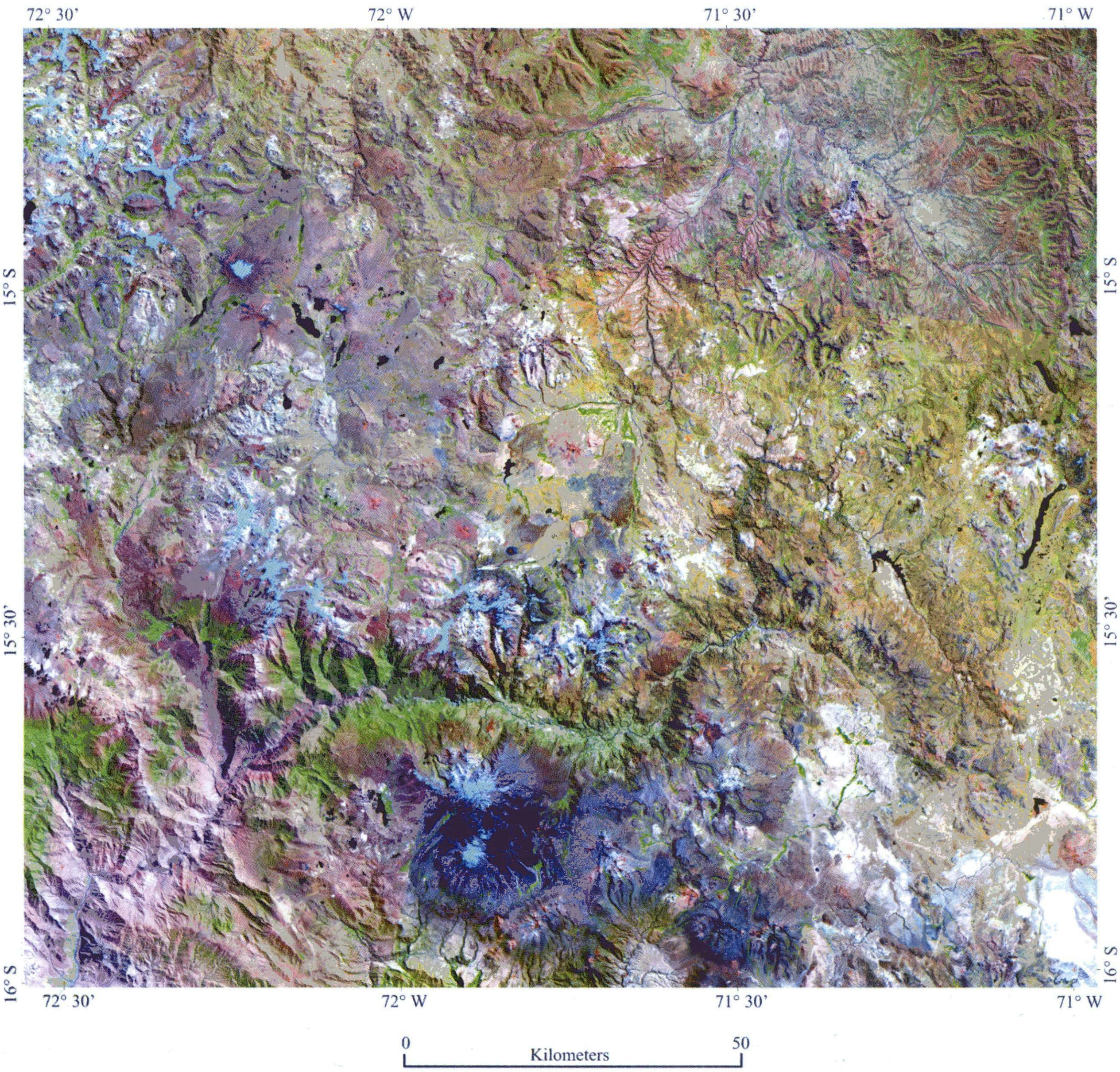


Fig. 4. A. Landsat image of the region of exposure of the Cailloma Tuff

ACKNOWLEDGEMENTS

The information on which this paper is based was collected at various times while the senior author was associated with Mauricio Hochschild y Cía. Ltda., Compañía de Minas Buenaventura S.A.A. and INGEMMET. We thank Ing. Agapito Sánchez for discussions of the Ignimbrita Confital.

REFERENCES

CALDAS V. & LA TORRE V. (1973).- Mapa geológico del cuadrángulo de Orcopampa. Instituto Geológico Minero y Metalúrgico, scale 1:100,000.

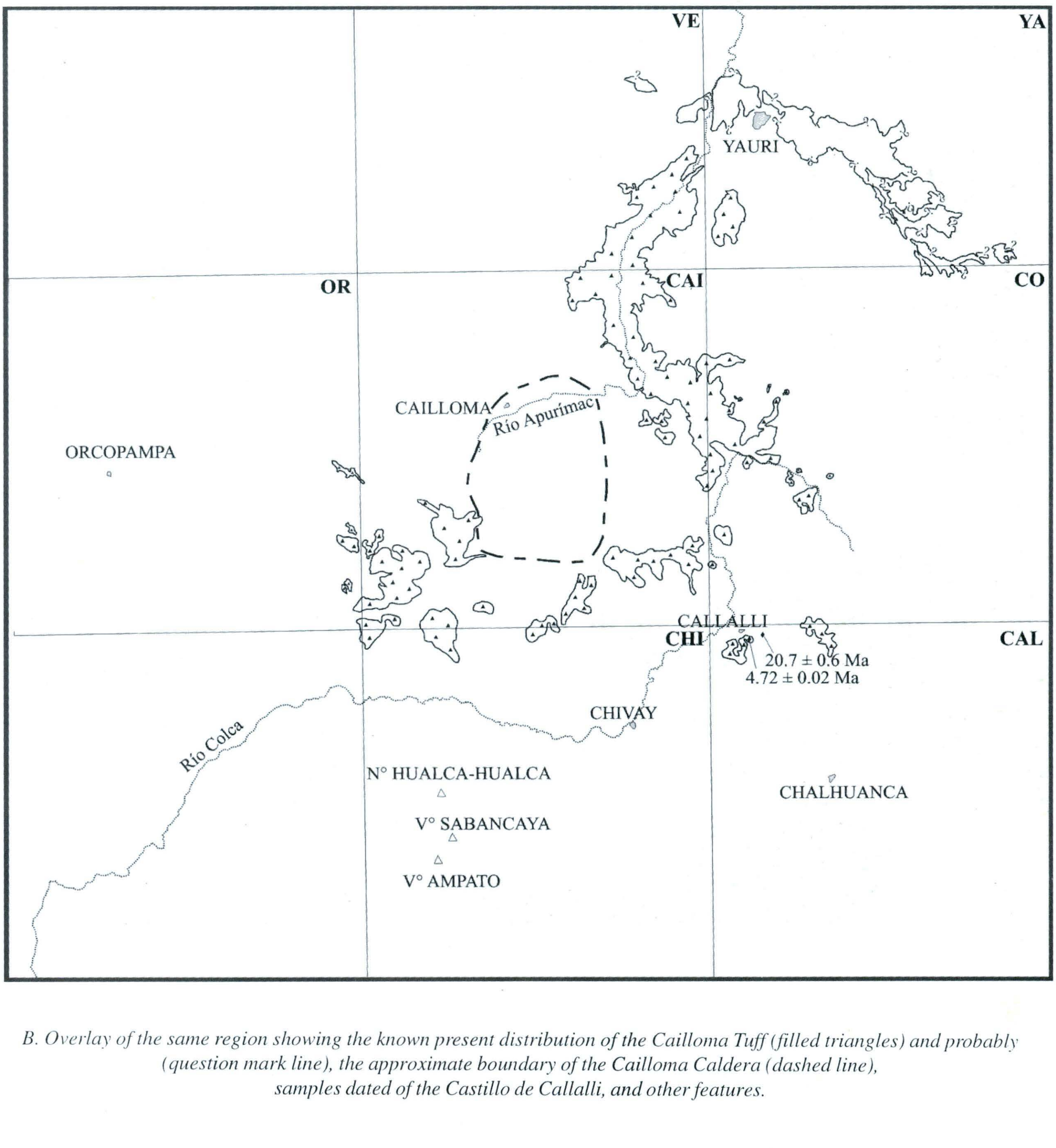
DÁVILA D. (1981).- Cailloma caldera: caldera tipo valle. *Bol. Soc. Geol. Perú,* 68, 25-31.

DÁVILA D., DÍAZ G., MONTOYA M. (1988). Mapa geológico del cuadrángulo de Cailloma. Instituto Geológico Minero y Metalúrgico, scale 1:100,000.

DE LA CRUZ N. (1995).- Mapa geológico del cuadrángulo de Yauri. Instituto Geológico Minero y Metalúrgico, scale 1:100,000.

DE LA CRUZ N. & LA TORRE O. (1995).- Mapa geológico del cuadrángulo de Velille. Instituto Geológico Minero y Metalúrgico, scale 1:100,000.

B



B. Overlay of the same region showing the known present distribution of the Cailloma Tuff (filled triangles) and probably (question mark line), the approximate boundary of the Cailloma Caldera (dashed line), samples dated of the Castillo de Callalli, and other features.

ELLISON R. & DE LA CRUZ J. (1985).- Mapa geológico del cuadrángulo de Callalli. Instituto Geológico Minero y Metalúrgico, scale 1:100,000.

HAUSBACK B., DEINO A., TURRIN B., MCKEE E., NOBLE D. & WEISS S. (1990).- New $^{40}Ar/^{39}Ar$ ages for the Spearhead and Civet Cat Canyon Members of the Stonewall Flat Tuff, Nye County, Nevada: Evidence for systematic errors in standard K-Ar age determinations on sanidine. Isochron/West, 56, 3-7.

HAWKINS M. & DE LA CRUZ N. (1985).- Mapa geológico del cuadrángulo de Condoroma. Instituto Geológico Minero y Metalúrgico, scale 1:100,000.

NOBLE D. (1979).- El Río Amazonas nace en una caldera de colapso – El emplazamiento geológico regional de las minas de plata de Cailloma y Sucuitambo. Private report, Compañía de Minas Buenaventura S.A., 2 p. and plates.

NOBLE D., NAVARRO P., MCKEE E. & QUISPESIVANA L. (2002a).- Eruptive history of the Pliocene Cailloma caldera, high plateau province of southern Perú. *Sociedad Geológica del Perú,* XI Congreso Peruano de Geología, Resúmenes, 202.

NOBLE D., NAVARRO P., QUISPESIVANA L. & SPELL T. (2002b).- Highly differentiated "topaz" rhyolite in the high plateau province of southern Perú. *Sociedad Geológica del Perú,* XI Congreso Peruano de Geología, Resúmenes, 203.

SWANSON K. (1998).- Geology of the Orcopampa 30 minute quadrangle, southern Peru, with special focus on the evolution of the Chinchón and Huayta calderas. Unpublished Ph.D. thesis, University of Nevada, Reno, Reno, Nevada, 316 p.

SWANSON K., NOBLE D., MCKEE, E. & GIBSON P. (1993).- Collapse calderas and other Neogene volcanic and hydrothermal features of the Chila Cordillera and adjacent areas, southern Peru. *Geological Society of America* Abstracts with Programs, 25, 5, 153.

APPENDIX
Analytical data for sanidine CCTTP

ID	$^{40}Ar/^{39}Ar$	$^{37}Ar/^{39}Ar$	$^{36}Ar/^{39}Ar$ (x 10^{-3})	$^{39}Ar_K$ (x 10^{-15} mol)	K/Ca	$\%^{40}Ar^*$	Age (Ma)	±1σ (Ma)
CCTTP, single crystal sanidine, J=0.0007633, NM-144, Lab#=52649								
02	3.445	0.0070	0.2975	2.29	73.2	97.5	4.62	0.03
14	3.419	0.0070	0.0740	2.02	73.3	99.4	4.67	0.04
09	3.463	0.0068	0.2208	2.60	74.6	98.1	4.67	0.03
06	3.448	0.0070	0.1136	3.30	72.6	99.0	4.70	0.02
08	3.432	0.0069	0.0235	3.56	74.3	99.8	4.71	0.02
03	3.779	0.0059	1.179	2.76	87.1	90.8	4.72	0.03
11	3.455	0.0103	0.0742	3.61	49.4	99.4	4.72	0.02
01	3.451	0.0072	0.0552	3.10	70.8	99.5	4.72	0.03
07	3.414	0.0075	-0.0728	2.06	67.7	100.6	4.73	0.04
05	3.492	0.0068	0.1803	3.59	74.5	98.5	4.73	0.02
10	3.432	0.0066	-0.0232	2.93	77.4	100.2	4.73	0.03
13	3.441	0.0066	0.0041	3.70	77.8	100.0	4.73	0.02
12	3.427	0.0065	-0.0566	2.05	78.9	100.5	4.74	0.04
15	3.429	0.0067	-0.0853	2.98	76.4	100.8	4.75	0.03
04	3.471	0.0071	0.0377	3.18	71.6	99.7	4.76	0.03
weighted mean		MSWD = 1.4	n=15		73.3 ±8.0		4.72	0.02*

Notes:

Isotopic ratios corrected for blank, radioactive decay, and mass discrimination, not corrected for interferring reactions.

Individual analyses show analytical error only; weighted mean age and total gas age errors include error in J and irradiation parameters.

n= number of fusion steps

K/Ca = molar ratio calculated from reactor produced $^{39}Ar_K$ and $^{37}Ar_{Ca}$.

* 2σ error