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Stratigraphy of the Carbonate, Black Shale, and Phosphate of the Pucará Group (Upper Triassic–Lower Jurassic), Central Andes, Peru

ABSTRACT

Within the Mesozoic fold-and-fault belt of west-central Peru between Lake Junín and Huancayo, the Pucará Group is subdivided into three formations. The rocks were originally described by Harrison (1944) and the formations were named from near Huancayo by Mégard (1968). They are: (1) Condorsinga Formation (top): limestones, shaly, sandy, bioclastic, and cherty; thickness is as much as 2900 m; (2) Aramachay Formation: bituminous shales and sandstones, cherts, and phosphatic rocks; thickness is as much as 600 m; (3) Chambara Formation: limestones, shaly, bituminous, and cherty; thickness is up to 1500 m.

Although relatively lacking in fossils diagnostic of age, the Chambara Formation is assigned a late Triassic age (Norian-Rhaetian); it is probably correlative with most of the Pucará Group of Cerro de Pasco area (Jenks, 1951; Haas, 1953). The other two formations are Early Jurassic in age (Aramachay: Hettangian in part to middle Sinemurian; Condorsinga: upper Sinemurian to upper Toarcian).

The Pucará Group represents a miogeosynclinal sequence, unconformably underlain by red clastic and volcanic rocks of the Permian Mitu Group, and disconformably overlain by clastic rocks of the Lower Cretaceous Goyllarisquisga Group or by red beds of the Middle Jurassic Cercapuquio Formation.

The Chambara Formation indicates a regionally uniform and relatively deep environment of deposition. The Aramachay represents predominantly an accumulation of fine clastics and much organic material in a deep marine basin, which was followed by, and was probably preceded by, deposition of diverse sedimentary facies revealing shifting and laterally variable marine environments. The limestone beds of the Condorsinga Formation show relatively uniform and shallower marine sea-floor conditions. Rates of deposition for the three formations individually, and for the group as a whole, in cm/1,000 yrs are: Chambara: 15; Aramachay: 5.7; Condorsinga: 12.5; Pucará Group, cumulative rate: 9.7.

INTRODUCTION

Regional Setting and Previous Work

Rocks of the Pucará Group, mainly limestones, are exposed in a broad zone within the Mesozoic fold-and-fault belt, on the high plateau (*altiplano*) of central Peru. The exposures are east of the Continental Divide, and have been traced continuously from beyond Goyllarisquisga on the north (Harrison and Wilson, 1960), south and southeast beyond Pazos (Fig. 1) (Narváez, 1972). Our work has dealt with the Group between Cerro de Pasco on the north and Huancayo on the southeast. A regional anticlinorium of pre-Triassic rocks passes through Tarma and Ricrán (Newell and others, 1953); east of this, there is another outcrop belt of Pucará rocks. This latter belt, however, is in the High Jungle geomorphic province, where exposures are few and geologic knowledge is very scant. Little data therefore are given in this report for the Pucará in this second belt.

Most of the area of the high plateau is deficient in plant cover and is also lacking in good exposures of the Pucará and other units. Many of the stratigraphic sections used in this report (Fig. 2) were measured across the slopes or floors of valleys and gullies (sections 6, 7, 9, 21), and across glaciated bedrock floors (sections 4, 11, 12, 16).

The Pucará Group was first described as the "Lower Limestones of Mesozoic age" (under-

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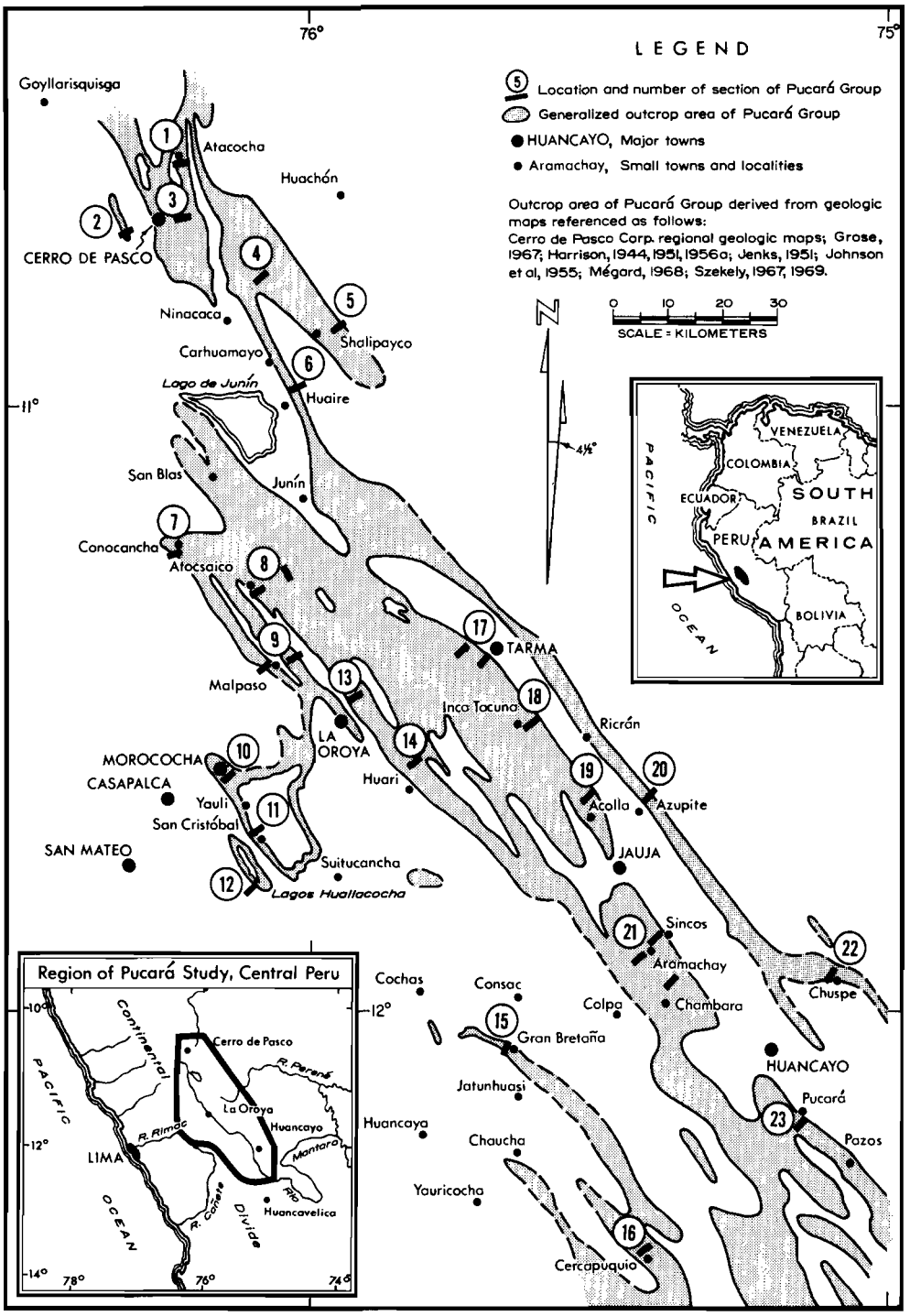

Figure 1. Regional location map of area of Pucará study, Central Andes, Peru.

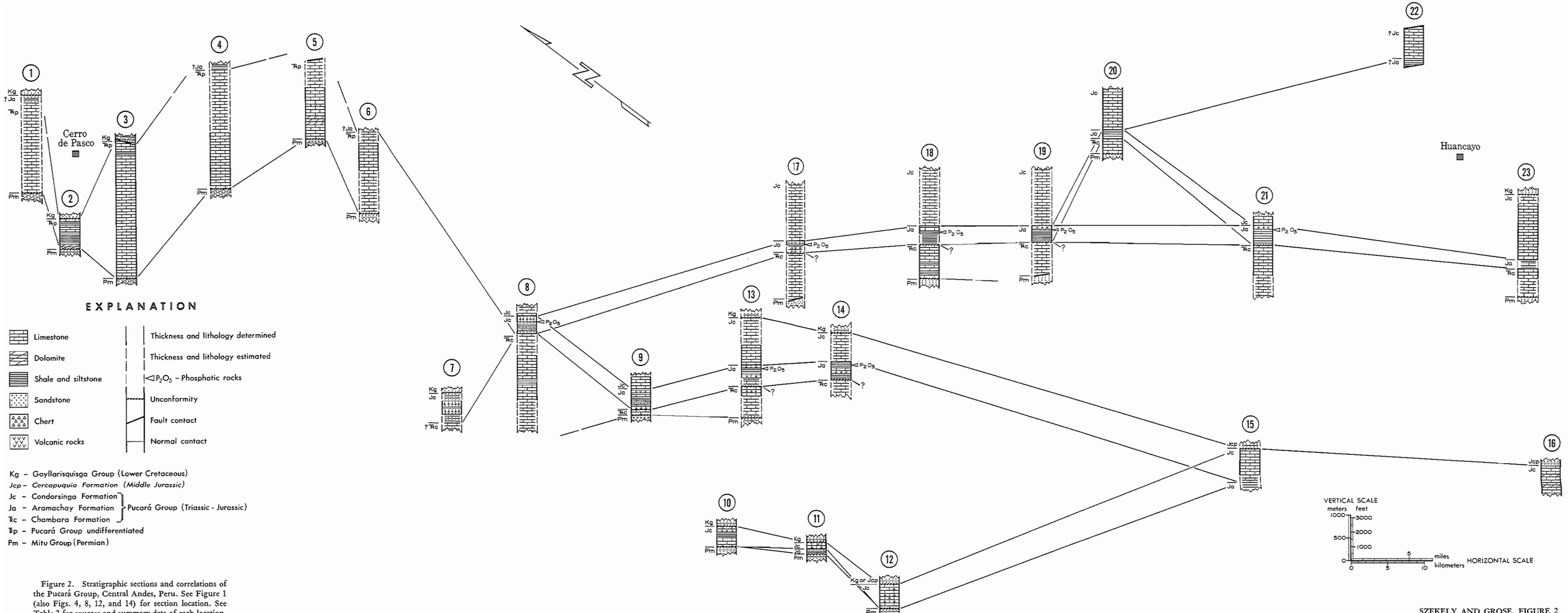

Figure 2. Stratigraphic sections and correlations of the Pucará Group, Central Andes, Peru. See Figure 1 (also Figs. 4, 8, 12, and 14) for section location. See Table 2 for sources and summary data of each location.

SZEKELY AND GROSE, FIGURE 2
Geological Society of America Bulletin, v. 83, no. 2

lying the Lower Cretaceous clastics) by McLaughlin (1924, p. 605). He gave the formation name "Pucará" to a sequence of limestones intercalated between the underlying upper Paleozoic Mitu conglomerates, and the overlying Lower Cretaceous Goyllarisquisga clastics at Pucará near Goyllarisquisga (Fig. 1), and he also suggested Pucará as a regional term for the Triassic-Jurassic limestone sequence. Pucará was raised to a group term by Jenks (1951), upon his study of the Triassic and younger formations in the Cerro de Pasco area; this paper follows Jenks' usage.

The rocks of the Pucará Group were studied and described by Harrison, following his regional field studies (1944, 1956a). His threefold subdivision (Harrison, 1944) of the Group for the area between Lake Junín and Huancayo is still essentially valid:

Upper Calcareous Series. Mainly middle Liassic, some upper Liassic fossils. Variable limestones, thin- and thick-bedded, as much as 1,300 m thick.

Lower Lias Shaly Series. Shales, colored, in part bituminous; lower Liassic ammonite horizons. 400 to 550 m thick.

Lower Calcareous Series. Limestones, bituminous, cherty. Upper Triassic fossils (no ammonites).

Mégard (1968) and Grose and Szekely (1968) set up the subdivision of the Pucará Group into the Condorsinga, Aramachay, and Chambara Formations, which correspond respectively to Harrison's three units as listed above (Table 1).

Near Cerro de Pasco, the Pucará Group is a single carbonate sequence. A study of this section led Jenks (1951) to his postulate of an eastern and a western facies of the Pucará, on either side of a major regional fault passing through Cerro de Pasco. Jenks indicates that the eastern facies (Fig. 2, section 3) is a very thick, monotonous sequence (more than 2,900 m) mainly of dark gray limestones in thick, massive units. Johnson and others (1955) found the Group in the Atacocha area (section 1) to be similar to Jenks' eastern facies. The western

TABLE 1. AGE ASSIGNMENTS AND CORRELATION TABLE OF THE PUCARÁ GROUP
(thickness in meters)

Area	Atacocha	Cerro de Pasco–Junin	L. Junin–La Oroya–Tarma–Jauja–Sincos	Huancayo–Pazos–Cercapuquio–Lircay
Reference	Johnson and others, 1955	Cox, 1949; Jenks, 1951; Haas, 1953	Harrison, 1944, 1956a; this paper	Mégard, 1968; Pardo and Narváez, unpub. data
Overlying Formation	L. Cretaceous Goyllarisquisga Gp. clastics	L. Cretaceous Goyllarisquisga Gp. clastics	L. Cr. Goyllar. Gp.; locally M.-U. Jurassic red beds	L. Cr. Goyllar. Gp. or M. Jurassic (Bajoc.) Cercapuquio red beds
Lower Jurassic: Toarcian, Pliensb., Sinemur., Hettang.	? ?	? ?	Condorsinga Fm (Upper Calcareous Series) 1,000 - 1,500	Condorsinga Fm 1,200
			Aramachay Fm (Lower Lias Shaly Series) 400	Aramachay Fm min. 50
			? ? DISCONFORMITY ? ?	? ?
Upper Triassic: Rhaet., Norian, Carnian	undivided Pucará Gp. min. 2,100	undivided Pucará Gp. W. facies ~ 630 E. facies ~ 2,900	Chambara Fm (Lower Calcareous Series) 500 - 1,500	Chambara Fm min. 180
	? ?	? ?	? ?	? ?
Underlying Formation	Perm. Mitu Gp.: red ss, cgl	Perm. Mitu Gp.: red ss, cgl, volc.	Perm. Mitu Gp.: volc. aggl., red ss, cgl	Unexposed

facies (section 2) is only about 630 m thick and consists of thin-bedded limestone and shale. Jenks established the correlation between the eastern and the western facies on the basis of similar faunas (Jenks, 1951, p. 205). We agree with Jenks' postulate of the two facies and do not in this paper bring further data to bear on this. The correlation of the units of the Pucará Group of Cerro de Pasco area with units to the south will be dealt with below (Fig. 2 and Table 2).

Present Work

This paper is based on detailed stratigraphic field work carried out by Grose in 1960, 1961, 1966, and 1967, and by Szekely in 1967.

CHAMBARA FORMATION

This, the lowermost unit of the Pucará Group, consists of Upper Triassic limestones and was named by Mégard (1968), following the usage of Grose (1961), the name being derived from the village of Chambara, south of Sincos (Fig. 1).

The formation was studied at seven localities between Junín and Huancayo; the lower contact, however, is exposed at only two localities (section 9 near Malpaso, and section 18, west of Ricrán). East of L. Junín, the Pucará Group (undivided), with which the Chambara Formation is considered to be correlative (Fig. 2), was studied in four sections. Section 5, near Shalipayco, has an excellent exposure of the base and lowermost 1000 m of the Pucará Group. In sections 5, 9, and 18, the base of the Pucará is in sharp and parallel contact with underlying red sandstones (section 18), with purple agglomerates (section 9), and with intermediate volcanics and coarse volcanic conglomerates (section 5); all of the latter belong to the Permian Mitu Group of clastic and volcanic rocks (Newell and others, 1953). Throughout the region, the contact is interpreted to be disconformable with local slight angular discordance.

The upper contact of the Chambara Formation was observed in five sections between Junín and Huancayo. It is parallel and is one of marked lithic contrast, and is interpreted as a disconformity (Fig. 3). The base of the Aramachay Formation is considered to be Hettangian-lowermost Jurassic. We think that the Chambara-Aramachay contact probably represents a hiatus, that is, emergence and non-deposition in the region, during part of the Rhaetian and part of Hettangian time.

Although there have been a number of fossil lots collected from the Chambara Formation between L. Junín and Pazos, an accurate age assignment cannot now be given, because no ammonites have been found. This is in contrast with the approximately correlative limestone sequence of the Rio Utcubamba area, northern Peru, which has provided an abundant ammonite fauna (Kummel, 1950). Shelly horizons from the Chambara have yielded brachiopods, pelecypods, gastropods, sponges, bryozoans, and echinoids. The presence of the brachiopod *Spondylospira*, and of the pelecypod *Pseudomonotis* (*Entomonotis*) *ochotica*, indicates the Norian stage of the Upper Triassic (Harrison, 1944; Kummel, 1950; Mégard, 1968).

The undivided Pucará of the Atacocha–Cerro de Pasco–Junín region has provided a number of fossil collections. Mollusks from the region, collected by Harrison, were described by Cox (1949) and gastropods, collected by Jenks, described in great detail by Haas (1953). Cox and Haas both concluded that the Pucará sequence here is Norian and probably lower Rhaetian in part. Haas argued against an age younger than upper Rhaetian for the upper parts of the Pucará sequence, on the basis that neither ammonites nor other fossils indicating the Liassic were found in the sequence. Three fossil collections of the Pucará were assigned to the Upper Triassic (Imlay, *in* Johnson and others, 1955). In one location near Atacocha, limestones close beneath the top of the Pucará yielded specimens of the Early Jurassic ammonite *Arietites* (Johnson and others, 1955, p.

Figure 3. Contact between the Aramachay (Ja) on the left and the Chambara (Tc) on the right. Concretionary limestone and cherty mudstone in basal part of Aramachay. Light color represents weathered metalliferous shale at left. View is to southeast from 5 km south of Aramachay village.

348). Our interpretation is that the Pucará Group (undivided) of the Cerro de Pasco–Junín area is Upper Triassic (Norian and Rhaetian). An extension of the age of the Group into the Early Jurassic is applicable in the Atacocha area, but because of lack of positive evidence, is not thought to be the case for the Cerro de Pasco and more southerly areas. There is sufficient correspondence of the fauna from the Pucará (undivided) of the Cerro de Pasco–Junín area, with that of the Chambara Formation to the south, to suggest that these two sequences are correlative. These interpretations are shown on the correlation chart, Table 1.

The above correlation between the undivided Pucará Group of the northern area and the Chambara Formation to the south seems supported by the measured sequence east of Atocsaico (section 8). The section, 964 m thick, consists of beds of dark, dense limestone with little chert, and beds of light-colored, bioclastic, calcarenitic, and sponge-bearing limestone. The measured section is overlain by an estimated 400 m of limestone to the top of the formation, and underlain by an estimated 600 m of limestone (base unexposed). The entire section has thus an estimated thickness of about 1,950 m; Harrison's estimate for the thickness of the Chambara in this area was 1,500 m (Harrison, 1956a). These thicknesses are transitional between the thickness of the formation in La Oroya–Tarma-Sincos region (700 m or more) and that of the eastern facies of the Pucará near Cerro de Pasco (about 2,900 m). See the isopach map of the Chambara Formation (Fig. 4).

The Chambara Formation or its equivalent is not exposed west of a line connecting San Blas, Atocsaico, and Morococha. The Yauli structural dome lies between Morococha and Suitacancha; Harrison, who named this feature, had inferred (1944) that the Pucará on its flanks lacked Upper Triassic rocks. This was confirmed for the San Cristóbal area (Tosi, 1956) and for our sections 11 and 12, which indicated that the Pucará sequence at both is of Early Jurassic age and that the Chambara Formation is absent. At Morococha, the Pucará limestones, locally termed Potosi (about 380 m thick, exclusive of sills), are also probably Lower Jurassic, although fossil evidence is lacking (Terrones, 1949).

Near Malpaso (Fig. 1, section 9), the 106-m-thick measured section of the Chambara is transitional between a complete section and an absent one. Two possible interpretations arise. In this western area, either there was little or no original deposition in Late Triassic time; or if there had been a complete Chambara sequence, it may have been wholly or partly eroded in an episode of emergence and erosion in latest Triassic-earliest Jurassic time. We favor the latter interpretation.

The most complete section of the Chambara known in the southern area is section 21 (Figs. 1, 2). The measured thickness is 621 m, with the base unexposed. Unpublished mapping by Grose revealed that the sequence is in reverse-fault contact (upthrust southwestern block) with Upper Tertiary tuffs and shales. Mégard measured a sequence of the Chambara (182 m) between Pucará and Pazos to the southeast. He regards this as a complete original thickness (Mégard, 1968). On the basis of field work in the same area, we believe that this is an incomplete thickness because of faulting at the base.

The facies pattern of the Chambara Formation could not be determined because of too few detailed sections. West of Ricrán (section 18), the Chambara is about 700 m thick, and consists of limy shales, dark, bituminous limestones with chert nodules, and lesser bioclastic and calcarenitic limestones (brachiopod-pelecypod-sponge beds). The other sections are in the southern part of the region (section 21), and consist of dark, shaly, dense limestones with much chert in nodules and veinlets (Fig. 5). The rock types suggest that in Norian-Rhaetian times, the predominant sediment accumulation was of lime muds, commonly bituminous and siliceous, on the floor of a marine basin.

In the region south and southeast of Cochas (Fig. 1), the only part of the Pucará Group that has been found exposed is the upper, Condorsinga Formation (Mégard, 1968; Szekely, 1969; Yates and others, 1951). It is not known whether or not the Chambara and Aramachay Formations exist in subsurface, and if they do, what their facies may be.

ARAMACHAY FORMATION

This middle formation of the Pucará Group was named by Mégard (1968, p. 37) for the well-exposed shaly strata in the vicinity of the village of Aramachay (Fig. 1), based on the field studies carried out previously by Grose (1961, 1967) and Szekely (1968). The type locality of the Aramachay Formation is at the site of the old Ichpachi mine, 2 km southwest of

TABLE 2. SUMMARY AND SOURCE DATA OF STRATIGRAPHIC SECTIONS OF THE PUCARÁ GROUP, CENTRAL ANDES, PERU
(Sections refer to those on Figs. 1, 2, 4, 8, 12, and 14)

Section	Locality	Chambara Formation	Aramachay Formation	Condorsinga Formation	Remarks
1	Atacocha-Chicrín area, 12 km north-northeast of Cerro de Pasco	*Pucará undivided*, est. thickness minimum of 2,100 m by Johnson and others (1955, p. 347); mainly Chambara	*Upper part of undivided sequence is probably equivalent to the Aramachay, at least in part*	*Absent*	*Rests with slight angular discordance on Mitu, and overlain disconformably by Goyllarisquisga*
2	7 km west and southwest of Cerro de Pasco near Yaraghuanca	Pucará undivided, probably Chambara equivalent; 627 m; Jenks (1951)	Probably absent	Absent	Significantly tectonically thinned. Disconformably overlain by Goyllarisquisga and underlain by Mitu; Jenks' western facies of the Pucará Group
3	2 to 8 km east of Cerro de Pasco	Pucará undivided, 2,931 m measured by Jenks (1951); probably all Chambara	Probably absent	Probably absent	Rests with slight angular unconformity on Mitu, and overlain with local, small, angular unconformity and channeling by Goyllarisquisga; Jenks' eastern facies of Pucará
4	On road to Huachon from Ninacaca between Lakes Huay Huay and Lulicocha	Chambara est. thickness 2,500 m from Harrison (1951, map no. 2); Szekely (1968) measured 1,091 m and tentatively correlated with Jenks	Lower Lias Shales of Harrison (1951) may be equivalent to Aramachay to south. Not known in Cerro de Pasco region to the north	Condorsinga possibly present and/or confused with Jenks' Pucará to the northwest (Jenks, 1951; Harrison, 1951)	Bottom of Szekely's measured interval may correlate with beds 75 m above base of Jenks' eastern facies (1951, p. 206); disconformably underlain by Mitu and conformably overlain by Lower Lias Shales (Aramachay?) (Harrison, 1951)
5	*East of Shalipayco near ridge* crest; 16 km east-northeast of Carhuamayo	*Chambara est. preserved* thickness 1,700 m from Harrison (1951, map no. 2); Szekely (1968) measured basal 1,085 m	*Eroded (modern)*	*Eroded (modern)*	*Disconformably overlying Mitu volcanic conglomerate; upper part of Chambara is faulted out on southwest*
6	2 km northeast of Huaire	Chambara est. thickness +1,700 m from Harrison (1951, map no. 2); Szekely (1968) measured 529 m in upper part of sequence	Probably present in subsurface to the west	May be present in subsurface to the west	Fossil zone 70 m above base of measured section may be equivalent to fossil zone high in section at Jenks 25 km to the northwest (Jenks, 1951, p. 208); disconformable on Mitu; top of section covered
7	Canyon just west of Conocancha	In subsurface (Harrison, 1956a)	Aramachay est. thickness 600 m (Harrison, 1956a). Szekely (1968) measured 285 m within sequence	Probably absent (Harrison, 1956a, Pl. 2)	Tectonically disturbed section; neither top nor bottom of Aramachay exposed; position of measured section impossible to correlate; Aramachay disconformably overlain by Goyllarisquisga (Harrison, 1956a)
8	At Atocsaico (Aramachay and Condorsinga), and 8 km east-northeast of Atocsaico east of unnamed lake (Chambara)	Chambara est. thickness 1,964 m by Szekely (1968), who measured 964 m that tops est. 400 m below Aramachay, and that is underlain by est. 600 m of limestones	Aramachay est. thickness 420 m. Szekely (1968) measured upper 395 m.	Condorsinga est. preserved thickness 200 m (Harrison, 1956a, Pl. 2). Szekely (1968) measured basal 76 m.	Chambara base not exposed. Unknown thickness of Condorsinga eroded (for map of area, *see* Harrison, 1956a, Pl. 2)
9	2 km west of Malpaso (Chambara and lower half of Aramachay) and 7 km northeast of Malpaso (Aramachay and Condorsinga)	Chambara thickness 106 m measured by Szekely (1968); *original* stratigraphic thickness probable	Aramachay thickness 452 m measured by Szekely (1968)	Basal 215 m measured by Szekely (1968); higher units covered and of unknown thickness	General area of décollement movement (Harrison, 1956a, Pl. 2)
10	Morococha	Absent	Probably absent	Measured 431 m including 51 m basalt sill by Terrones (1949); mineralized, unfossiliferous	Entire sequence, locally termed Potosi, lies disconformably on Mitu and under Goyllarisquisga, and is probably all Condorsinga
11	Yauli–San Cristóbal area; ridge north of Carahuacra-Volcán mine; 2 km northwest of San Cristóbal	Absent	Aramachay thickness 108 m measured by Szekely (1968)	Condorsinga thickness 113 m measured by Szekely (1968)	Disconformably underlain by Mitu and overlain by Goyllarisquisga; this section is in good agreement with section by Tosi (1956); see map of area by Harrison (1944)

TABLE 2 *(continued)*

Section	Locality	Chambara Formation	Aramachay Formation	Condorsinga Formation	Remarks
12	Lago Huallacocha Baja, south of southwest tip of lake; 8 km south-southwest of San Cristóbal	Absent	Probably absent	Entire Pucara interval probably represents the Condorsinga; thickness 509 m measured by Szekely (1968)	Disconformably overlying channeled (10 m relief) surface on Mitu volcanics. Disconformably overlain by clastics probably of Cercapuquio Formation
13	3 km east of and 7 km northeast of La Oroya	Chambara est. thickness 650 m from Harrison (1944); upper exposed part, 168 m, measured by Grose (1967)	Aramachay est. thickness 450 m from mapping by Grose (1967). 259 m in upper part measured by Grose (1967) and Szekely (1968)	Condorsinga est. thickness 1,000 m from Grose (1967); lower 416 m measured by Szekely (1968)	Measured thicknesses are tectonically reduced several hundred meters from original stratigraphic thicknesses; disconformably overlain by Goyllarisquisga
14	6 km north of Huari	Chambara upper 300 m mapped by Grose (1967); unknown thickness in subsurface	Aramachay 353 m measured by Grose (1967); interval poorly exposed	Condorsinga est. thickness 600 m (Grose, 1967)	Original stratigraphic thicknesses are tectonically reduced several hundred meters; disconformably overlain by Goyllarisquisga
15	Southwest of Lago Azulcocha in Jatunhuasi–Gran Bretaña district	Probably present in subsurface	Probably present in subsurface	Condorsinga reported 700 m thick in Jatunhuasi area by McLaughlin (1924); exposed upper 558 m measured by Szekely (1968)	Type area of Condorsinga Formation (McLaughlin, 1924, p. 604); disconformably overlain by Cercapuquio Formation
16	Just north of Cercapuquio	Probably present in subsurface	Probably present in subsurface	Upper 585 m of Condorsinga measured by Harrison (1956b), who regarded it as Upper Triassic	Toarcian fossils discovered by Mégard (1968, p. 39-45) in rocks formerly described as Upper Triassic (Chambara) by Harrison (1956b, p. 22); overlain conformably by Cercapuquio Formation
17	3 km southwest and 10 km west of Tarma	Chambara, ±1,000 m, based on reconnaissance mapping by Grose (1967)	Aramachay, est. 250 m thick and upper 72 m measured by Grose (1967)	Condorsinga est. preserved thickness 1,200 m (Grose, 1967)	Chambara-Mitu contact is décollement surface along and close to original disconformity; unknown thickness of Condorsinga eroded
18	East of Inca Tacuna at topographic divide on road from Tarma to Jauja	Chambara, 722 m measured by Szekely (1968)	Aramachay interval, poorly exposed, 391 m estimated by Szekely (1968) and upper 130 m drilled by Cerro de Pasco Corp.	Condorsinga est. preserved thickness 1,200 m (Grose, 1967)	Chambara resting disconformably on Mitu with no shearing apparent along contact; unknown thickness of Condorsinga eroded
19	4 km north-northwest of Acolla	Chambara, est. 700 m exposed thickness by Grose (1967); basal portion faulted out against Mitu	Aramachay, est. 329 m thick, modified from Harrison (1940, p. 17)(Marco section); upper 90 m measured by Grose (1967)	Condorsinga est. preserved thickness 1,200 m (Grose, 1967)	Chambara in fault contact with Mitu; unknown thickness of Condorsinga eroded
20	2 to 5 km to northeast of Azupite	Chambara 314 m thick; Harrison's Lower Calcareous Series (1944, p. 4)	Aramachay, 192 m thick, Harrison's Lias Shale (1944, p. 4)	Condorsinga, +860 m preserved thickness, Harrison's Upper Calcareous Series (1944, p. 4)	Stratigraphic equivalencies indicated are general; section is probably tectonically thinned, and upper part is eroded
21	1 km northeast of Aramachay (Chambara); 2 km southwest of Aramachay (Aramachay); and 9 km south-southeast of Aramachay (Condorsinga)	Chambara est. 1,000 m thick by Grose (1961); Szekely measured upper 621 m exposed above lower faulted-out part	Aramachay, 408 m thick measured by Grose (1961) and Szekely (1968)	Condorsinga est. preserved thickness 250 m by Grose (1961); Szekely (1968) measured lowermost 191 m	Type locality of Aramachay measured 2 km southwest of Aramachay. Lower part of Chambara in fault contact with Tertiary sediments; unknown thickness of Condorsinga eroded
22	Chuspe, 18 km northeast of Huancayo	Probably present in subsurface	Aramachay(?) upper 123 m measured by Harrison (1951, p. 18-19)	Condorsinga(?) lower 638 m measured by Harrison (1951, p. 18-19)	Partial section bounded by faults is "Jurassic and Triassic sequence" of Harrison (1951, map no. 1); formational correlations are questionable
23	2 km south of Pucará	Chambara est. 600 m thick (Mégard, 1968, structural cross sections); upper 182 m measured by Mégard (1968, p. 112)	Aramachay unit of Mégard (1968, p. 112). 47 m thick represents only lower(?) part of the Aramachay; estimated thickness of 203 m by Grose and Szekely	Condorsinga est. 1,400 m thickness from Mégard (1968); lower 1,200 m measured by Mégard (1968) and Szekely (1968)	Chambara is disconformable on Mitu where not faulted in Pucará area; Condorsinga is disconformably overlain by Goyllarisquisga 13 km south of Pucará (Mégard, 1968)

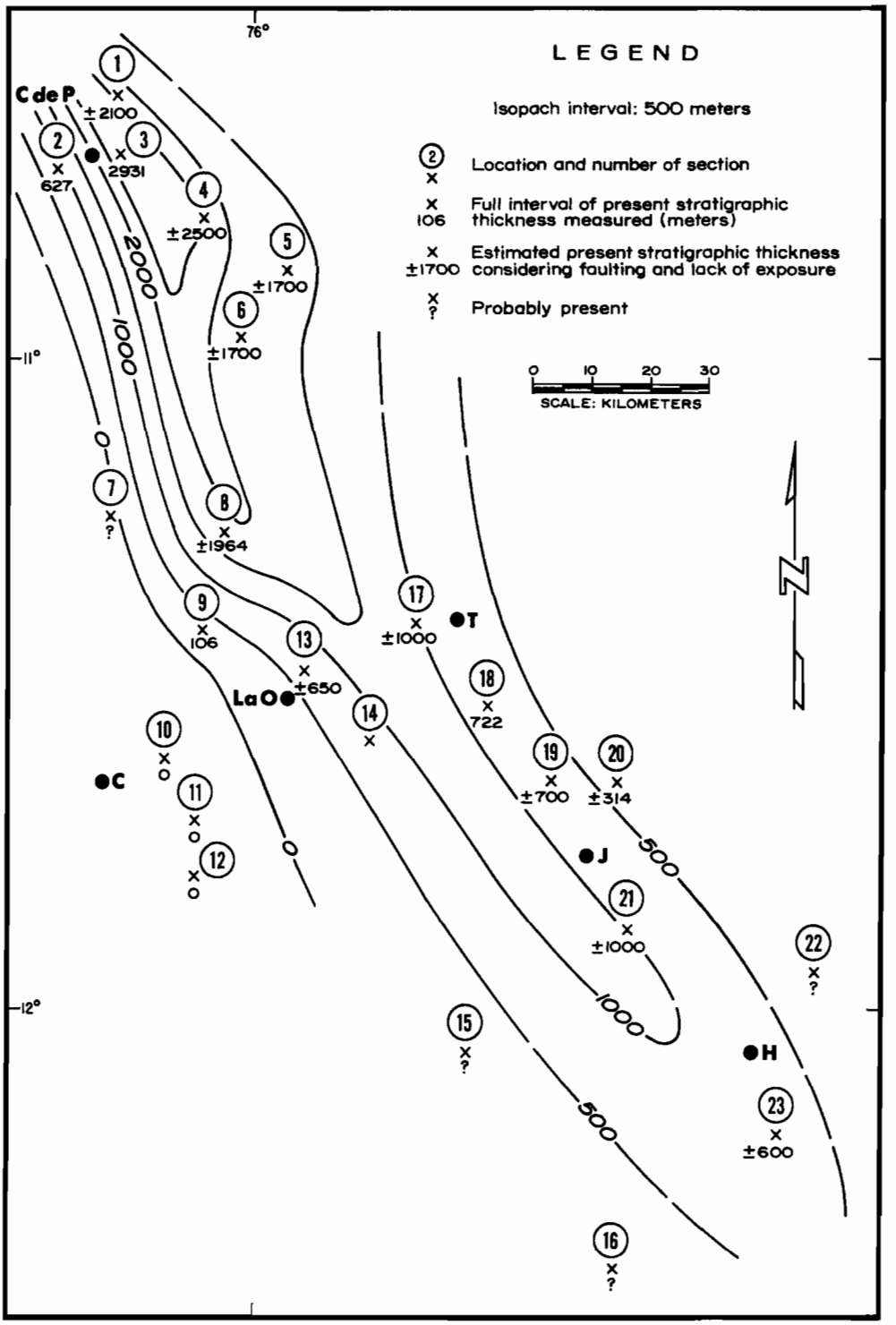

Figure 4. Isopach map of Chambara Formation.

Aramachay, where the unit is fully preserved on the southwest flank of a regional syncline (Fig. 6, section 21). Throughout the region from south of Huancayo to L. Junín (Fig. 1), the Aramachay Formation comprises a distinctive shale break of poor outcrops and strike valleys (Fig. 7) between the more resistant and prominent limestones of the Chambara and Condorsinga Formations. Harrison (1944) first recognized the persistence and mapping value of this unit and referred to it as the Lower Liassic Shaly Series.

Of the three formations in the Pucará Group, the Aramachay is the most difficult to observe because of poor outcrops and unusual susceptibility to tectonic deformation. At only three locations were we able to measure a full, exposed section of the Aramachay. They are section 9 at Malpaso, section 11 at Yauli-San Cristóbal, and the type section 21 at Aramachay (Figs. 1, 2, 6). At ten other locations where the Aramachay has been studied (Fig. 8), the sections are tectonically complicated by thrust faulting and diapiric shearout in tight folds; thus only parts of the formation are present in these areas. Original thickness and generalized lithologic nature were estimated on the basis of field mapping in each case by the authors and are in corporated into the stratigraphic correlation diagram (Fig. 2). Aramachay beds are exposed at many other places but are so extremely deformed as to be of little value in a stratigraphic study of the formation as a whole.

Figure 5. Interbedded dense limestone (light color) and chert (dark) from upper part of Chambara. Exposed 4 km southeast of Aramachay village.

The areal limits of the Aramachay as a mappable unit of the Pucará Group are fixed only on the southwest in the vicinity of Morococha, Yauli, and Lagos Huallacocha (Fig. 1). The thin remnant of the Aramachay Formation at Yauli is absent both north and south where Condorsinga limestones rest disconformably on Permian Mitu red beds and volcanic rocks (Figs. 2, 9). On the south, the Aramachay shales are believed to occur in the subsurface (sections 15 and 16), since the style of tight folding expressed in the exposed Con-

Figure 6. Type locality of Aramachay Formation 2 km southwest of Aramachay village. View to northwest. Light shale is weathered equivalent of black bituminous shale. Dip is steep to right. (Refer to Fig. 2, section 21.)

Figure 7. Contact between Aramachay shale (mainly unexposed) in strike valley to right and Condorsinga limestone on ridge. Phosphate and chert in transition zone. View is to southeast from 11 km west of Tarma.

dorsinga limestones demands one or more décollement horizons at depth, and these shales effect a local and regional décollement nearly everywhere under the Condorsinga. Southeast of Huancayo, Mégard (1968) traced the Aramachay to the limit of his quadrangle map 15 km southeast of Pazos (Fig. 1), and Guizado and Landa (1964) mapped the Pucará Group undifferentiated 15 km farther southeast. Along the northeastern margin of the region, the reconnaissance mapping of Harrison (1944) has pointed out the occurrence of Pucará beds in a long, tight synclinal complex passing through Ricrán, in which his Lower Liassic Shaly Series, which we correlate with the Aramachay, are locally differentiated (sections 20 and 22). Farther northeast, undifferentiated Triassic-Jurassic (Pucará?) strata are believed to occur on the eastern slopes of the Andes (Bellido and others, 1956). The farthest north that strata are known in this region which may be lithologically equivalent to the Aramachay are the lower Liassic shales (Harrison, 1951, map no. 2) that extend to about 20 km southeast of Cerro de Pasco (section 4, Fig. 1). Limestones in the topmost part of the undifferentiated Pucará Group at Atacocha (section 1), however, are correlative with part, at least, of the Aramachay Formation (*see* under Chambara Formation above; also Table 1). Finally, on the northwest, the extent of the Aramachay and the Pucará Group in general is not known, because of extensive cover of Cretaceous and Cenozoic rocks. Isopach trends strongly indicate that the Aramachay thickens markedly (Fig. 8) and suggest that the formation may persist in the subsurface for many kilometers in a northwesterly direction. The Aramachay Formation as a useful mappable unit may be restricted to the L. Junín-Huancayo region when compared with the apparently much greater areal extent of the Chambara and Condorsinga limestones which comprise the bulk of the regionally persistent and prominent Pucará Group.

The rocks of the Aramachay Formation are essentially black bituminous shale with chert and phosphatic mudstone and limestone in the upper part. A measured section of the type locality (section 21; Fig. 6) is presented in Table 3. The unweathered shale is dark gray to jet black, soft where clayey, hard where siliceous, and finely laminated where volcanic ash layers are present. The unusual blackness of the rock is caused by bituminous organic matter pervasive as matrix in amounts assayed up to 8 percent by weight. The local farmers have at times successfully burned the shale as "coal." Upon weathering, however, the organic matter is readily oxidized, which leaves a porous, "punky," light-tan to cream-colored rock characteristic of the outcrops of Aramachay. In arroyos and canyons where erosion is rapid, the light shale grades downward through darker

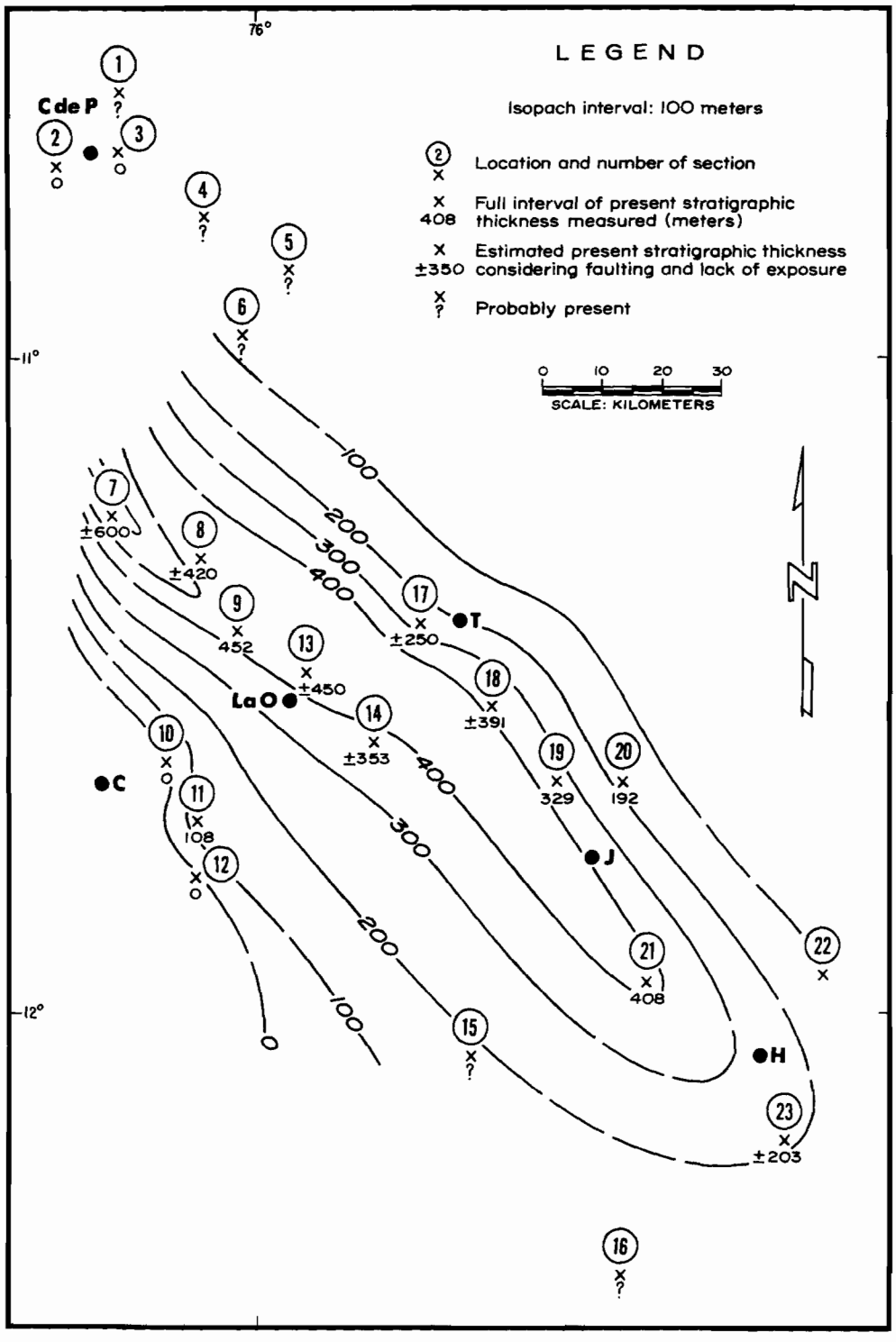

Figure 8. Isopach map of Aramachay Formation.

Figure 9. Top of Pucará limestone (Condorsinga Formation) in right foreground, resting directly and disconformably on Mitu clastics and volcanics, center background. West flank of Yauli dome dipping southwest. View is to southeast. Ridge is 2 km southeast of San Cristóbal.

shades of brown and gray to rare exposures of fresh jet-black shale.

One 18-m-thick zone (Table 3) in the black shale at the type locality is abnormally high in vanadium and selenium. It is a metalliferous shale remarkably similar in many ways to the vanadiferous shale zone of the Meade Peak Member of the Phosphoria Formation in southeastern Idaho (Davidson and Lakin, 1961; Gulbrandsen, 1960; Vine, 1969). The rare mineral sincosite [Ca $(VO_2)_2$ $P_2O_8 \cdot 5H_2O$?] first described by Schaller (1924) and named from the town of Sincos was derived from this zone in the Aramachay. Preliminary description and analyses of this zone are given by Larson and Welker, (1947, p. 52–55) and it is referred to briefly by Baragwanath (1921, p. 781) as a possible source for the vanadiferous asphaltites known in the region.

The top 30 to 90 m of the Aramachay Formation contain a complexly variable sequence of phosphatic and cherty rocks which have been studied in detail in the region between Chambara on the southeast and La Oroya-Tarma on the northwest. The phosphate and chert may extend beyond these limits, but additional work will be required to ascertain this. The phosphate occurs in two distinct zones characteristically as collophane (carbonate fluorapatite) pellets in clayey mudstone, limy mudstone, siliceous mudstone, and phosphate-pellet sandstone (Fig. 10), limestone, and phosphorite. Individual limy and clayey phosphatic zones, containing 5 percent to about 20 percent P_2O_5 by weight, range in thickness from less than 1 m to about 20 m. Interbedded with the phosphate zones are prominent thin- to thick-bedded spiculitic cherts, and thinner limestones, mudstones, and sandstones (Fig. 7). Lithologic succession, in spite of locally significant departures, of the upper part of the Aramachay Formation, from lower to higher units, is: bituminous shale and mudstone increasingly phosphatic upward, phosphatic mudstone and phosphorite, chert, and phosphatic and cherty limestone. The entire sequence from the bituminous metalliferous shale zone upward through bituminous and siliceous shale, phosphatic mudstone, chert, cherty limestone, to limestone is notably similar to, but considerably thicker than, the thoroughly studied sequence of part of the Phosphoria Formation in southeastern Idaho (McKelvey and others, 1959).

The contact between the Aramachay and the underlying Chambara (Fig. 3) is parallel at the very few places possible to observe it, and it is marked by relatively abrupt lithologic change downward from black mudstone and chert with prominent concretions (Fig. 11) and basal glauconitic sandstone to cherty limestone and interbedded sandstone of the Chambara. No phosphate has been found in the basal portion of the Aramachay or in the upper portion of the Chambara. In addition to the physical evidence, paleontologic evidence suggests a hiatus

TABLE 3. MEASURED SECTION OF ARAMACHAY FORMATION AT TYPE LOCALITY*

Thickness in meters	Lithology: megascopic field description
	Condorsinga Formation: gray, fossiliferous, oölitic, slightly phosphatic limestone
	Conformable contact
	Aramachay Formation:
8	Limestone, phosphatic, cherty, medium crystalline, pelletal, tan-gray, medium- to thick-bedded, est. 10 percent P_2O_5.
9	Mudstone, phosphatic, sandy, tan, thick-bedded, est. 10 percent P_2O_5, with local thin phosphorite beds.
5	Limestone, sandy, tan, thick-bedded.
24	Chert, locally shaly and limy, tan to gray, thin- to medium-bedded, spiculitic.
5	Sandstone and siltstone, graywacke, silty to medium-grained, tan, laminated and micro-cross-bedded, with six green volcaniclastic beds each 15 to 30 cm thick, lenticular.
12	Sandstone, clayey, phosphatic, silty to medium-grained, brown, locally volcaniclastic, est. 3 percent P_2O_5.
61	Mudstone, silty, cherty, locally slightly phosphatic and limy, dark-gray to black, thin- to medium-bedded, with few beds of limestone, bituminous, siliceous, black, hard, usually less than 1 m thick. Less limestone and phosphatic mudstone toward bottom.
185	Shale, bituminous, siliceous, black, thin- to medium-bedded, weathers tan, gray, yellow, contains 1- to 10-mm beds of white volcanic ash less than 1 percent by volume increasing toward bottom. *Between 40 and 50 m from bottom, contains* abundant *Arnioceras ceratitoides*.
18	Shale, highly bituminous, vanadiferous and seleniferous, jet-black, laminated to medium-bedded, soft to hard, weathers tan to yellow, contains volcanic ash beds 1 to 20 mm thick less than 3 percent by volume. At top, contains flattened ammonites *Angulaticeras*, abundant *Arnioceras ceratitoides*, and *Arnioceras anguticostatus*.
41	Shale, bituminous, siliceous, slightly limy, black, thin- to medium-bedded.
40	Mudstone, cherty, brown to black, with marker bed of silty limestone concretions 1 m in diameter at top (Fig. 11) and cherty, glauconitic, brown sandstone at bottom.
408	Total thickness
	Disconformable contact
	Chambara Formation: cherty, gray limestone, with minor volcaniclastic(?) sandstone beds.

Ammonite identifications by M. K. Howarth (1968, written commun.).
*See Figure 6, section 21.

reflecting part of the Rhaetian and possibly some of the Hettangian (Table 1). It is possible that this contact is not disconformable everywhere in the region of study. The contact between the Aramachay and the overlying Condorsinga is one of essentially continuous transitional sedimentation and intertonguing of chert and phosphatic mudstone with limestones (Fig. 7).

Ammonites from the Aramachay (Table 4) indicate the Sinemurian Stage of Lower Jurassic (terminology of Jurassic stages and zones is *after* Dean and others, 1961). Ammonites have been previously reported from the San Blas area (Tilmann, 1916; Boit, 1940); Atocsaico (Harrison, 1956a); La Oroya area (Harrison, 1944); Yauli-San Cristóbal area (Tosi, 1956); and south and southwest of Huancayo (Mégard, 1968; *see* Fig. 1). Szekely collected diagnostic ammonites in 1967 from Atocsaico, east of La Oroya, and southeast of Aramachay. The oldest documented age of the lower part of the Aramachay is Hettangian, based on ammonites collected by Harrison (1944, p. 7) from only one locality near Ricrán. Mégard made extensive fossil collections in the Huancayo-Pazos-Cercapuquio area without finding Hettangian fossils, although this does not preclude the possibility that the lower part may be Hettangian in that area also. The youngest documented age of the Aramachay is upper Sinemurian, based on fossil evidence south of Huancayo (Mégard, 1968, p. 37–39). The age assignment of the Aramachay Formation in the region is shown on Table 1.

Facies within the Aramachay Formation are imperfectly known and are likely to remain so, because of nearly omnipresent tectonic deformation relatively concentrated in the weaker shales of this unit. The thickest and most uniform bituminous shale, including the occurrence of the metalliferous shale, and the most extensive accumulation of chert and phosphate are apparently concentrated along a part of the zone of greatest thickness of the Aramachay extending from northwest of Huancayo to La Oroya–Tarma area (Fig. 8). The bituminous shale, chert, and phosphate may continue to the northwest. However, the exposed section at Malpaso (section 9) contains interbedded bituminous shales, sandy and limy mudstones, and cherty limestones. The incomplete sections at Atocsaico (section 8) and at Conocancha (section 7) are more sandy with less bituminous shale and chert. The westernmost known occurrence of Aramachay at Yauli–San Cristóbal (section 11) comprises 62 m of black shaly limestone and limy shale in the lower part, and 46 m of mainly silty sandstone with some chert in the upper part lying conformably beneath the Condorsinga limestone. At sections 10 and 12, the Condorsinga lies disconformably on Permian Mitu red beds (Fig. 9). Aramachay rock types are not known in the wide area to the south of section 12, although on general paleogeographic grounds (Harrington, 1962) the oceanward direction for Early Jurassic time is expected to have been southwestward. Southeast of Huancayo along the axis of maximum thickness, the Aramachay is little known, but it appears to thin and consist mainly of bitumi-

Figure 10. Cross-bedding in phosphatic and volcanic sandstone in upper part of Aramachay Formation. Measured section is 7 km southeast of Aramachay village.

nous shale and limy mudstone. Facies of the Aramachay in the belt northeast of the Tarma-Huancayo anticlinorium (Fig. 1) are very poorly known. Meager data gleaned from Harrison (1944, p. 7; 1951, p. 18–19) (sections 20 and 22), from Guizado and Landa (1964, p. 41–44), and from reconnaissance trips by the present authors suggest that the Pucará Group may be a threefold unit in that region and that the Aramachay is essentially a cherty, dark limestone with minor interbeds of marl and sandy shale. Facies changes within the Aramachay in a northward direction in the region of study are not known, because shales (possibly Aramachay equivalent) overlying thick Pucará limestone (herein called Chambara) have been mapped in reconnaissance only near Ninacaca (section 4) by Harrison (1951). In the Cerro de Pasco region, the entire Pucará Group (Jenks, 1951; Johnson and others, 1955) is mostly limestone and is correlated lithologically and paleontologically with the Chambara Formation (Table 1). The Chambara is overlain disconformably by clastics of the Cretaceous Goyllarisquisga Formation. Therefore, if the Aramachay Formation ever did cover the northern area, it apparently was removed by

Figure 11. Marker bed of concretions of silty, bituminous limestone in face of bedding in lower part of Aramachay Formation. Six km south of Aramachay village.

erosion in Jurassic time. Near Goyllarisquisga (Fig. 1), Harrison and Wilson (1960, p. 32) indicate that 30 to 300 m of limestone are probably Lower Jurassic. On the basis of lithology and scant fossil content (crinoids and pelecypods), this limestone seems to represent the Condorsinga rather than the Aramachay.

The highly organic shale and the phosphate and chert which characterize the Aramachay Formation reflect a depositional environment

TABLE 4. FOSSIL LIST*

Age assignment	Genera determined	Localities; sections of present report (numbers)†; and listed in previous works (small-case letters; see below)
Lower Jurassic		
Sinemurian Stage—lower *tumeri* zone	*Microdero-ceras*	21, a
tumeri or *semicostatum* zone	*Arnioceras*	8, 9, 13, 21, a, b, c, e, f
	Phyllo-ceratidae	a
semicostatum zone	*Agassiceras*	8, a
	Arietites, indeterminate species	8, 11, a, b, e, f
bucklandi zone	*Vermiceras*	8, 11, 13, a, c, e
	Boucaulticeras	a
	Plesechioceras	a
	Angulaticeras	21
	Coroniceras	c
Hettangian stage	*Psiloceras*, *Caloceras*	d

*Ammonites from the Aramachay Formation.
†The ammonites from the sections listed in the present report (collected by Szekely) were identified and age assignments given by M. K. Howarth, British Museum (Natural History); May 1968, written commun.
a - Huancayo quadrangle, Mégard, coll.; Mégard, 1968, p. 37–38.
b - Lircay area, Narváez, coll.; Pardo, unpub. data, 1968.
c - Oroya area, and d - Ricrán area, Harrison, coll.; Spath *in* Harrison, 1944.
e - Atocsaico (same section as our no. 8), Harrison, coll.; Harrison, 1956a.
f - San Blas and La Oroya areas (various collectors); Tilmann, 1916; Boit, 1940.

distinctly different from that of the Chambara and Condorsinga Formations. Lack of medium- and coarse-grained detritus suggests that land or source areas were distant. Preservation of organic matter in the fine muds, pelletal phosphate, undisturbed microlaminations of volcanic ash, unfragmented ammonites, and lack of shallow-water features of sorting and wave action collectively indicate a restricted euxinic basin environment of deposition in deep, quiet water. A regional reconstruction of lateral facies changes within the Aramachay seems nearly impossible. However, by analogy to similar sections of carbonaceous shale, phosphorite, chert, and limestone (in that upward and lateral sequence) known elsewhere in the world (Sheldon, 1964; McKelvey and others, 1959), the Aramachay appears to reflect a regressive phase of marine deposition in a semienclosed deep tectonic depression on a continental shelf or upper slope (or both) in an environment of upwelling, cold, phosphate-rich water. The highly nutrient waters supported abundant marine life, the remains of which accumulated on an anaerobic bottom and were preserved as organic matter and fossils in the black shales. The phosphatic mudstones, limestones, and minor sandstones, becoming more abundant toward the top of the sequence, indicate increasingly shallow deposition in a slightly reducing and oxidizing environment that gradually merged upward into the aerobic shallower platform environment of widespread carbonate deposition.

The sediments of the earlier transgressive phase beginning with the carbonate shelf of the Chambara limestones proceeding upward through chert, phosphate, and carbonaceous shale—the reverse or mirror image of the regressive phase—are apparently preserved only in part in this region. Basal sections of the Aramachay in the very few places observed contain no phosphate and very little chert. As further work is done in the region, a fully preserved transgressive sedimentary sequence may be discovered, although it is possible that one or more of the lithologic types never were deposited during transgression. However, a hiatus is inferred between the Chambara and Aramachay on the basis of lithologic and faunal break as described earlier.

Facies similar to the bituminous shales of the Aramachay are reported in the Utcubamba Valley area, Departmento de Amazonas, of northern Peru. The Chilingote Formation of bituminous limestone and calcareous shale contains Hettangian fossils, and the overlying Suta Formation of similar lithology, Sinemurian fossils (Tilmann, 1916, p. 638; Kummel, 1950, p. 258; Santiani, 1965). No phosphatic rocks from this northern area have been described. No evidence exists to suggest whether the northern and central Peru basins were connected or separate in Early Jurassic time.

CONDORSINGA FORMATION

The upper limestone unit of the Pucará Group was named Condorsinga Formation by Mégard (1968) because west of Huancayo this is the same formation as the limestone which, as McLaughlin reported (1924, p. 604), was locally known as the Condorsinga limestone in the Jatunhuasi coal-mining region (between Consac and Chaucha, Fig. 1).

We studied this formation at sections 8, 9, 13, and 21, where only the base of the formation is exposed and was measured (Fig. 12). Parts of the complete Pucará Group at sections 11 and 12 are considered to represent the Condorsinga (Table 2).

Fossils collected by Mégard from the Condorsinga in the Huancayo-Pazos-Cercapuquio area provide the best evidence to date on the

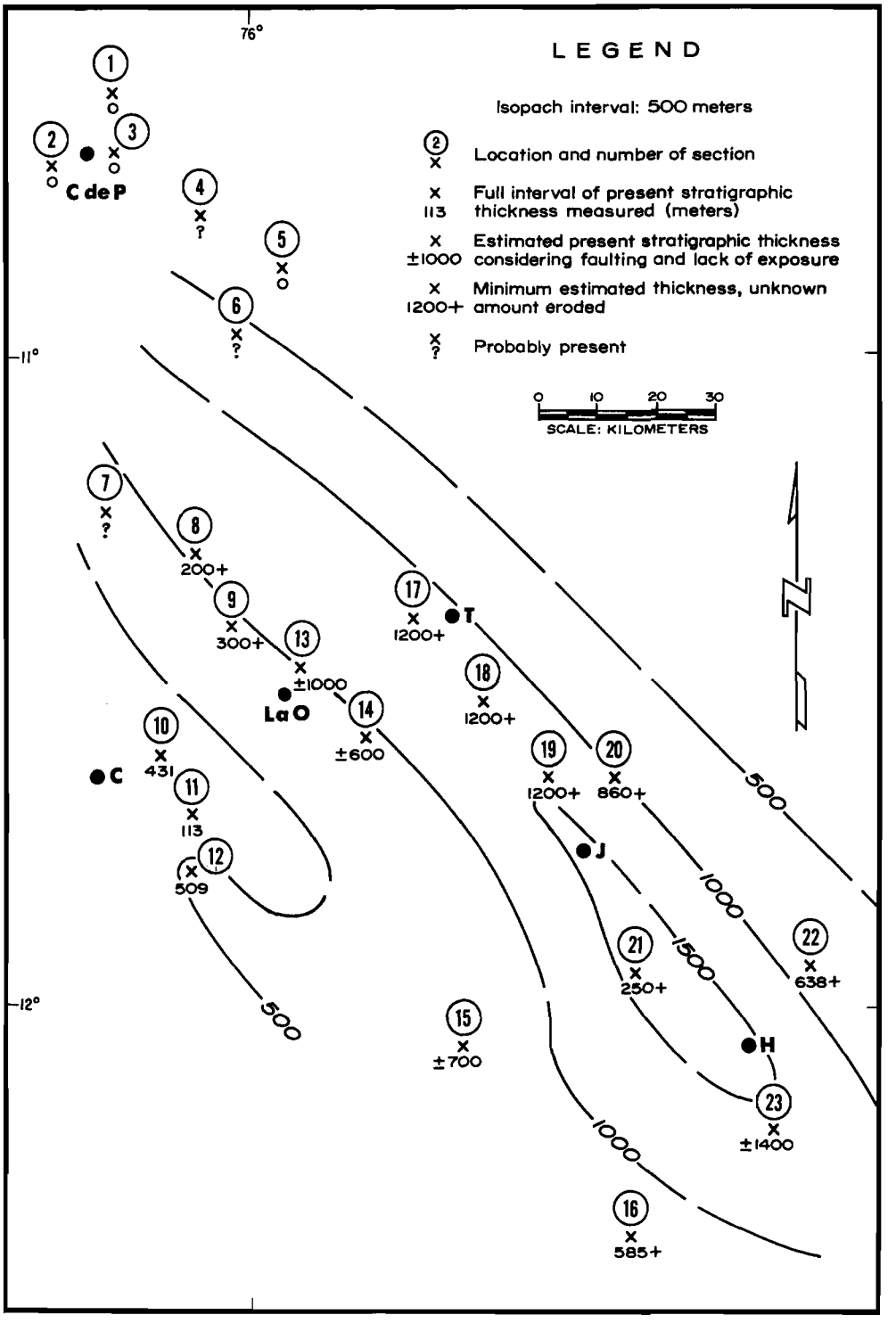

Figure 12. Isopach map of Condorsinga Formation.

age of this formation. From his list of fossils, we give here that of ammonites (identifications and age assignments by O. A. Pardo, *in* Mégard, 1968, p. 40–41):

Phymatoceras, *Esericeras:*	Upper Toarcian
Harpoceras, *Dactylioceras:*	Lower Toarcian
Arieticeras:	Upper Pliensbachian
Androgynoceras, *Coeloceras*, *Uptonia:*	Lower Pliensbachian
Oxynoticeras, *Eoderoceras*, indet. arietitids:	Upper Sinemurian

A graphoceratid(?) ammonite collected by Mégard from what is probably the top of the formation was indicative to him that the upper age limit may be "Lower Aalenian" (lowermost Bajocian). The base of the formation is Upper Sinemurian.

For parts of the region studied, the Aramachay-Condorsinga contact is in agreement with the concept of an intertonguing facies transition. Studied sections show that the base of the Condorsinga is markedly cherty (chert nodules and interbeds) in the following areas (Fig. 1): section 23 south of Huancayo (Mégard, 1968), the area southwest of Sincos (unpub. detailed sections by Grose) between sections 8 and 21, and sections 11 and 12 in the Yauli–L. Huallacocha Alta area (Fig. 13). In the highland between Jauja and Tarma, the basal Condorsinga is not, or is only very slightly, cherty (unpub. detailed sections by Grose, sections 13, 18); from La Oroya northward, this interval is also noncherty (sections 8, 9; Harrison, 1956a).

There are not enough complete sections of the Condorsinga known in the region to support more than a preliminary interpretation of thicknesses and facies (Fig. 13). The Condorsinga sequence near Huancayo and Pucará (Pazos) is very thick (minimum thickness at section 23 is 1,130 m; 1,200 m near Pazos; *see* Mégard, 1968). Within the highland bordered by Malpaso, La Oroya, Jauja, and Tarma, the formation is very thick, and we could measure no continuous section. Harrison reported (1944) a sequence corresponding to the Condorsinga of more than 800 m near Ricrán on the east, and of about 1,300 m near La Oroya where Grose (1967) estimated a total thickness of about 1,500 m (Fig. 12). These figures for the southeasterly zone east of Malpaso–La Oroya–Colpa indicate that for this

Figure 13. Lower part of Condorsinga Formation. View south from 1 km south of Aramachay village.

zone at least, the Sinemurian to Toarcian was a period marked by a high rate of subsidence and of sedimentation.

The Condorsinga or its equivalent is exposed at a number of localities west of the southeast-trending zone indicated above (Fig. 12). In the Morococha mining district, the Pucará equivalent is known as the Potosi limestone (data from Terrones, 1949); the upper 185 m consist of limestones (horizons A to D), and two limestone conglomerates (the Churruca breccias). The lower 195 m are dolomites to limestones, and a sandstone-shale bed (the two Laura and the E and F horizons). Because this is an area of strong faulting, mineralization, and recrystallization, no fossils have been reported and age assignment is tentative. We consider the entire interval of 380 m (exclusive of local sills) to represent the Condorsinga.

In the comparatively thin (220 m) Pucará sequence near San Cristóbal (section 11; Tosi, 1956; Fig. 9), the topmost member, 85 m of massive, cherty, shaly limestone, may represent the Condorsinga in part or whole.

At Lago Huallacocha Alta (section 12), the Pucará sequence is completely exposed; all of it is considered to represent the Condorsinga Formation. It is 509 m thick. The basal 77 m of dense limestone is overlain by 220 m of massive, shaly, bituminous, and very cherty limestone; above are 213 m of massive, shaly, and cherty limestones, bioclastic limestone (corals, brachiopods, gastropods, pelecypods), and biocalcarenitic limestone (crinoid, oölite). At Gran Bretaña (section 15), a measured 560-m interval represents a minimum thickness of the formation (base unexposed); for this, the type area of the Condorsinga, McLaughlin gave a thickness of 700 m. The base of the Condorsinga is not exposed west of Chaucha, in the area between Chaucha and Cercapuquio, where Petersen (1961) gave a minimum thickness of about 500 m; nor at Cercapuquio (Mégard, 1968). Near Huancavelica (Yates and others, 1951, p. 6), the 200 m of basal limestones, with base unexposed, again represent the incomplete Condorsinga Formation.

There has not yet been systematic geologic mapping along the Continental Divide and west of the line joining Morococha–Lakes Huallacocha (locality 12), west of Cochas-Huancaya-Yauricocha-Cercapuquio (Fig. 1). Heim (1948) and Hillebrand (F. Mégard, 1969, personal commun.) described a series of dark, fossiliferous, thick-bedded and cherty limestones which probably represent the Condorsinga Formation in the upper Cañete valley northwest of Huancaya.

The formation has lithofacies similar to those of the Chambara; dark-gray to black, shaly, dense limestone (section 15; Harrison, 1944); dark-gray, bituminous, very cherty limestone (section 12). However, there are also facies which are not represented in the Chambara. These include massive, thick-bedded, light-gray to buff (fresh), white-weathering limestones and calcilutites ("marls") (sections 13, 18); and coral-bearing, bioclastic limestones (sections 12, 13, 15). Fine to coarse, bioclastic-shelly limestone with gastropods, pelecypods, and brachiopods are more abundant in this formation than in the Chambara. Section 23, which is the most complete one that we studied, is made up largely of massive, light- to dark-gray, shaly limestones, with bioclastic interbeds. A very coarse shelly limestone bed about 350 m from the observed top of the sequence contains the following mollusks: abundant large *Weyla alata*, *Modiolus s. l.*, Pteriacea indet., *Entolium* aff. *E. liasianum*, ?*Camptochlamys*, *Plagiostoma*, ?Pleuromyidae (determinations by N. J. Morris, 1968, personal commun.).

The facies of the Condorsinga indicate that some of the sediments were carbonaceous and in part siliceous lime-muds that were deposited under reducing conditions; more, however, accumulated on well-aerated, relatively shallow marine banks as lime muds to light-colored silts and sands, in part oölitic and bioclastic. The fossiliferous zones with gastropods, pelecypods, and brachiopods or corals (or both) in particular indicate shallow marine floors of carbonate deposition.

Because the top and even the main part of the Condorsinga Formation are commonly unexposed in the region, there is only scant information on the ending of Pucará sedimentation. In the Cercapuquio and Pazos areas, and farther southeast in the Department of Huancavelica, the Condorsinga is overlain by a unit of unfossiliferous red and gray sandstones and siltstones, which Mégard named the Cercapuquio Formation (about 800 m thick at the type section). This is overlain by a limestone unit which Mégard (*after* Weaver, 1942, p. 161) called the Chunumayo Formation; this yielded collections of ammonites and other fossils indicating a Bajocian (Middle Jurassic) age (Mégard, 1968; Steinmann, 1929, p. 77; Lissón

and Boit, 1942, p. 46; O. A. Pardo, unpub. data, Servicio de Geología y Minería). According to Mégard, the Chunumayo Formation may also range in age into the Bathonian and perhaps the Callovian, however there are no paleontologic data at present to support this.

Red beds of sandstones and shales overlie the Condorsinga at the following other localities: Chaucha, Gran Bretaña-Jatunhuasi, near Cochas, Lago Huallacocha Baja-section 12 (above observations by Szekely), and at Morococha (the Potosi red shales; Terrones, 1949). These red beds have been considered to be the basal part of the Lower Cretaceous Goyllarisquisga Group of heterogeneous clastics (Wilson, 1963; Szekely, 1967). However, at the more southerly of these localities, where correlation with the Cercapuquio Formation is likely, and possibly at the other localities, the red beds above the Condorsinga may represent Middle Jurassic continental sedimentation, therefore post-Condorsinga regression, emergence, and erosion. The Chunumayo Formation in the stratigraphic sequence near Cercapuquio and Pucará to the southeast, indicates a renewed transgression and marine limestone deposition, at least in these areas.

The Pucará Group (Condorsinga Formation or older horizons) is overlain disconformably by Lower Cretaceous clastics of the Goyllarisquisga Group near San Cristóbal (section 11), in La Oroya-Tarma-Jauja region (Harrison, 1944; and our observations), near Huancayo (Mégard, 1968), and in the Cerro de Pasco area (Jenks, 1951). The Pucará-Goyllarisquisga contact is most commonly parallel and disconformable. The most direct interpretation is that these latter areas had been emergent and undergoing erosion in post-Pucará Jurassic time.

REGIONAL SUMMARY

The Pucará Group represents a thick sequence of marine shelf and miogeosynclinal carbonate and shale sedimentation along the western margin of the Brazilian craton and the eastern margin of the Pacific Ocean floor. The Group covers a period of geologic time from latest Carnian through Toarcian (medial Late Triassic through late Early Jurassic) in the southern part of the region and from Norian through Rhaetian (Late Triassic) in the Cerro de Pasco region. The Group is stratigraphically discontinuous from adjacent strata; disconformably beneath are red clastics and volcanics of the Permian Mitu Group, and disconformably above are clastic rocks of the Lower Cretaceous Goyllarisquisga Group and, in the southern part of the region, red beds of the Middle Jurassic Cercapuquio Formation (Table 1).

Although palinspastic reconstruction would expand the area of outcrop of Pucará rocks several tens of kilometers in a northeast-southwest direction, total present stratigraphic thickness variations (Fig. 14) indicate that the axis of maximum sedimentation was elongate northwest-southeast generally parallel with the modern regional tectonic strike and generally coincident with the *altiplano* Andean geomorphic province.

Paleontologic dating of the Pucará Group and its individual formations can be rather closely related to the absolute time-scale (Geol. Soc. Phanerozoic time-scale, 1964) for the purpose of calculating duration and rates of deposition which are summarized as follows:

Chambara Formation: latest Carnian to end of Rhaetian, 202 to 194 m.y. B.P. or 8 m.y.; 1200 m thickness in La Oroya–Tarma region. Rate of deposition: 15 cm/1000 yrs.

Aramachay Formation: mid-Hettangian to mid-late Sinemurian, 191 to 184 m.y. B.P. or 7 m.y.; 400 m thick in La Oroya area. Rate of deposition: 5.7 cm/1000 yrs.

Condorsinga Formation: mid-late Sinemurian to end of Toarcian, 184 to 172 m.y. B.P. or 12 m.y.; 1500 m thick in Huancayo area. Rate of deposition: 12.5 cm/1000 yrs.

Pucará Group: latest Carnian to end of Toarcian, 202 to 172 m.y. B.P. or 30 m.y.; 2900 m thick in La Oroya–Tarma region. Rate of deposition: 9.7 cm/1000 yrs.

Knowledge of equivalent Pucará stratigraphy on both the northeast and the southwest of the region of study is nearly totally lacking. To the northeast, strata designated as Triassic-Jurassic are known in only the most general reconnaissance fashion because of very poor exposures, lack of geologic study, and intense tectonic deformation and plutonic activity. To the southwest, if Pucará rocks ever did exist, they apparently have been eroded, buried, and/or metamorphosed and intruded. Therefore, we hold little hope of ever gaining much more significant knowledge on Pucará stratigraphy immediately adjacent to our region of study on the northeast and on the southwest. However, in adjacent regions to the northwest and to the southeast along trend of the presently preserved Pucará sequence, numerous occurrences

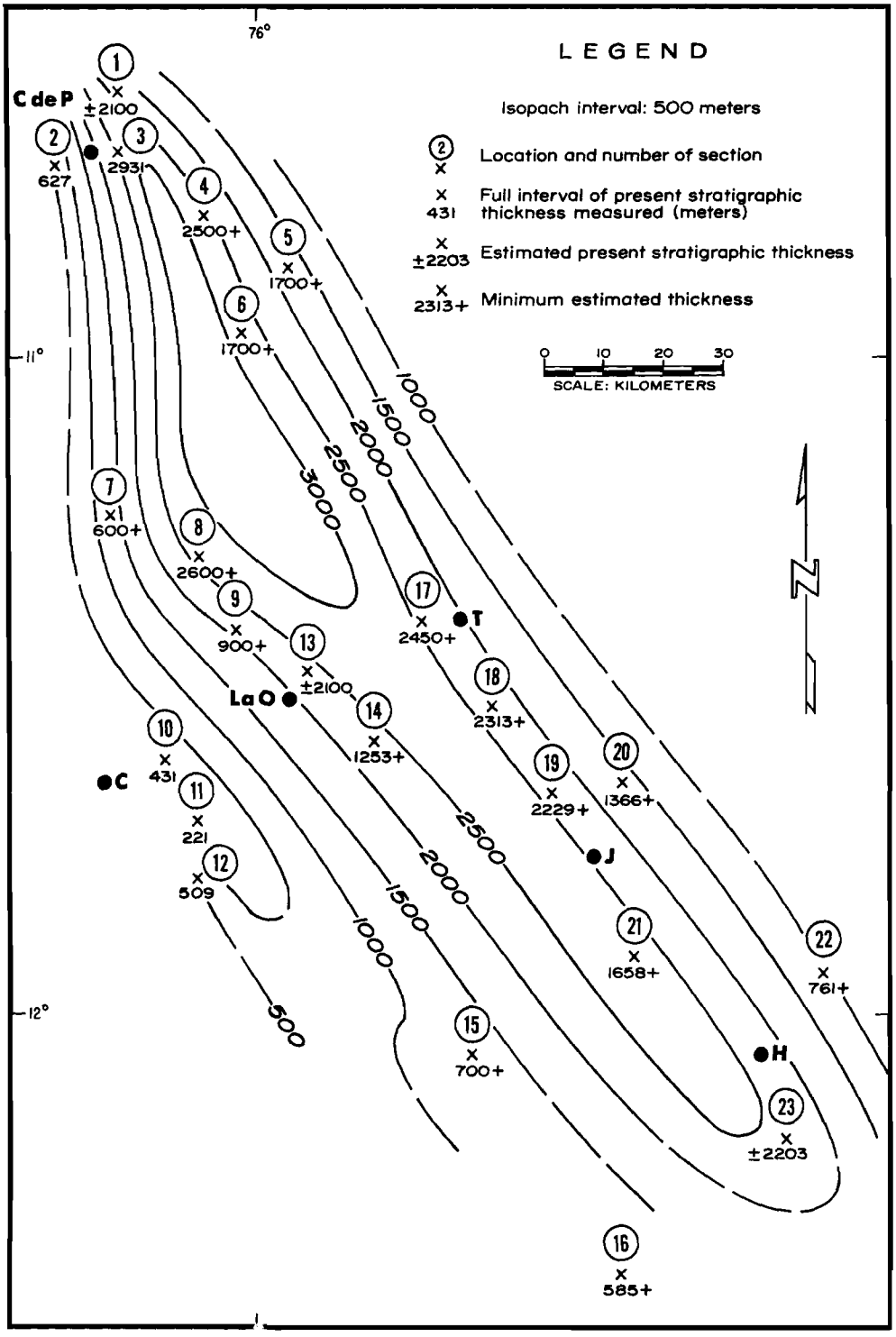

Figure 14. Isopach map of Pucará Group.

of equivalent strata are probably preserved. These await further study and integration with Mesozoic strata known in northern and southern Peru into a regional Andean Triassic-Jurassic paleogeography.

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