IMPERIAL COLLEGE

OF SCIENCE & TECHNOLOGY

APOLOBAMBA

1959

THE EXPLORATION BOARD.

Crossing one of the stepped crevasses on the Azucarani glacier

The East Soral Peak

1. Acknowledgements

Many people and institutions gave generously of their time or money to support the Apolobamba expedition. Without this support the expedition would not have been possible. The members of the expedition are extremely grateful for this assistance and wish to thank the following:-

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British Visqueen Ltd., Condrups Ltd., Pullin Optical Co., Eveready, Barr & Stroud Ltd., Moorlands Ltd., Huntley & Palmer Ltd., Horlicks, Glaxo Laboratories., Boots & Co., Colemans Ltd., Tate & Lyle, Featherware Ltd., Kiwi Polish Co., Van de Burgh & Jurgens Ltd.

2. Introduction G.C. Bratt

In February '57 it appeared that permission to enter Pakistan would not be granted to the I.C. Karakoram expedition so members began searching for an alternative area in South America. An unmapped area containing unclimbed peaks was sought and found in the NUDO DE APOLOBAMBA on the Bolivian-Peruvian border. However permission to enter Pakistan was finally granted and the Apolobamba idea dropped.

Early in '58 organisation of an expedition to carry out a survey and geological studies in the Apolobamba region during the summer of '59, was begun by Bratt, Hopkins and Melbourne. Requests for support were made to and granted by the I.C. Exploration Board, the Mount Everest Foundation, the Royal Geographical Society and the Club Andino Boliviano.

In June '58 notices calling for students to join the expedition were displayed around the College. All applicants were interviewed by a panel consisting of Prof H.H. Read, Asst. Prof.A. Stephenson, Mr. P.F. Taylor, 11 members of the Exploration Board, together with Mr. R. Garnet (I.C. Union President), G.C. Bratt and W.H. Melbourne. The team chosen was - Bratt, Ewart, Garrard, Jenkinson, Melbourne and Smith.

After selection of the members of the party the work of preparation began in earnest under the control of W.H. Melbourne. Bratt could do little more than advise during most of the preparatory stages as he was then in Patagonia.

The food and equipment packed in tea chests was dispatched from London on May 4th to travel by sea to Arica and then rail to La Paz. Ewart left London on June 2nd as he was to work with Dr. G. Francis', British Museum expedition in Peru before joining the I.C. party at Cojata on July 14th. Bratt and Melbourne left London on July 7th and the rest of the party followed after their examinations on July 20th. The size of the party was increased in La Paz when two Bolivians, Caraffa and Vanancio joined.

The plan of the expedition was originally as follows - the party would assemble in La Paz on July 14th and drive by truck (arranged by Sr. Farwig of the C.A.B.) the 200 miles to Pelechuco Pass picking up Ewart en route. Ewart and Garrard with Vanancio were then to work alone for the first month doing a geological traverse to Tambopata. The rest of the party (Bratt, Caraffa, Jenkinson, Melbourne and Smith) were to carry out a survey of, make geological investigations in and climb the principal peaks of the unmapped area bounded by the Sorals to the north and the Matchu Soochi Coochi ridge to the south. In the latter part of the trip the party would unite to complete the work in this unmapped area.

The expeditions plans were considerably modified by unforseen circumstances, particularly the strike by Italian seamen on June 9th. All members were booked to travel on Italia line ships and so had at the last moment to seek alternative passages. The field work had also to be curtailed because of changes in schedule of the Italia ships on which the return passages were booked. Ewart was so delayed that he cancelled his arrangements with Dr. Francis and because of the uncertainty of the date of arrival of Garrard, Jenkinson and Smith, the rest of the party left La Paz four days ahead of them.

The plans of Ewart and Garrard were modified to include an investigation of the Cojata, Trapiche and Poto regions and the Tambopata traverse was cut short at Sina because the geology was unrewarding. The rest of the party worked from the east instead of the west as intended, of the hypothetical 'Soral' valley (indicated by a dotted creek on the existing map) and extended their activities to valleys both north and south of the intended boundaries.

Although the field work of the expedition was limited to six weeks it managed to accomplish - a plane table and geological survey of 150 square miles of unmapped country, a geological survey of the country between Cololo and Sina, the ascent of fourteen virgin peaks of about 18,000 ft, some useful meteorological and glaciological observations and a collection of plants and lichens for the British Museum.

3. Personnel

G.C. Bratt

The members of the expedition, their colleges, position on the expedition and their responsibilities during preparations are given below:-

G.C. Bratt	R.C.S.	Leader and Surveyor	
W.H. Melbourne	C & G	Organising Secretary, Surveyor	
A. Ewart	R.S.M.	Geologist, Geology, visas permission	
J.W. Jenkinson	C & G	Surveyor	Equipment
A.W. Smith	R.S.M.	Geologist	Food and First Aid
P. Garrard	R.C.S.	Geologist	Travel arrangements
J. Macl#ay	C & G	Reserve	

As none of the first six members withdrew, Macl#ay did not join the expedition in the field.

The party was further strengthened in Bolivia by the inclusion of Carlos Caraffa a climber from the C.A.B. and Vanancio, a Bolivian porter (see section 5).

Smith, Bratt, Jenkinson, Melbourne, Ewart, Garrard.

On the 31st a seventh peak was bagged and the party moved to Camp 5 at the head of the Rio Sanches Cochu. From there it was hoped to climb the eastern Sorals and survey the area. A reconnaissance by Bratt and Jenkinson indicated that the party would have to set up camps to the north of the Sorals if they were to be climbed. The party then spent six days climbing the five summits of the eastern Sorals and completed the survey of the Rio Sanches Cochu and a valley to the north.

On the 11th August the party returned to Camp 3 and began the survey and reconnaissance of the Palomani basin. A camp (camp 9) for the climbing of the western Sorals was set up on 12th August. Between the 11th and 19th the whole party operated in the Palomani basin adding two more peaks to the list and completed the geological and topographical surveys of the region.

On the 19th August the party split once again. Smith and Ewart set out on an abortive attempt on the Katantica peak.

Bratt and Melbourne completed glaciological and survey work in the Pelechuco Pass; Jenkinson and Vanancio carried surplus gear to Suches and Garrard moved off to complete geological work between Suches and Cololo.

The party was reunited again on 23rd August at Suches. Because of shipping arrangements it had been intended that only Melbourne, Ewart and Garrard should return to La Paz, the other three would remain in the field for a further 10 days. However shipping schedules had altered again, a rush evacuation had to be made and the whole party returned to La Paz on August 25th.

5. Club Andino Boliviano Co-operation G.C. Bratt

The president of the Club Andino Boliviano (C.A.B.) Senor G. Farwig was contacted early in 1959 to obtain information on local conditions. Since members of the C.A.B. had been with the German party to the Apolobamba region they were able to give the expedition valuable information on access to the area and availability of transport within it. But the C.A.B. assistance did not end at this. They offered to

a) make a trip to the region prior to the arrival of the expedition in Bolivia to arrange for mules.
b) provide motor transport to and from the area
c) make contact with the expedition during ~~our~~ its stay in the field
d) arrange for some of their members to accompany the expedition.

This wonderful offer was accepted and carried out to the letter. One young climber Carlos Caraffa accompanied and climbed with the expedition from July 13th - 29th and a porter Vanancio (an employee of a member of the C.A.B.) was employed as a porter during the whole of the field work. Both gave invaluable assistance to the expedition.

Both Sr. Farwig and his wife gave up much time to entertaining the expedition while it was in La Paz and their help as interpreters made buying of food, arrangement of passages etc. much easier.

Thus the work of the expedition was greatly reduced and its success partly due to the efforts of the C.A.B. and particularly Sr. Farwig.

6. GEOLOGICAL REPORT

A. Ewart
P. Garrard
A.W. Smith

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Maps in Folder at End of Report:

a) Map 1

b) Stereograms A - L

c) Sections Across The Area

INTRODUCTION

1 (i) AREA AND BASE MAP

The Apolobamba area was partially surveyed and mapped in 1911-13 on a scale of 1:250,000 by the Peru-Bolivia Border Commission under the auspices of the Royal Geographical Society.

The area falls naturally into three topographical regions. The mountains proper, with peaks rising to over 19,000 feet above S.L., form an arcuate range which is convex northwards. They provide the watershed between streams draining S.W. to L. Titicaca and N.E. to the Amazon Basin. Much of this mountain area lies under permanent snow.

In the West, from Poto to Pinuni, are prominent hills and escarpments of sandstone.

The central part of the area consists of an extremely flat, high level plain, known as the 'pampa', which is sharply demarcated from the sandstone scarps to the west. The eastern border of the pampa, however, passes through a transitional zone of foothills before the mountains are reached. These foothills form a 3 - 4 mile wide belt of rolling, grass-covered country and comprise the thick, unsorted, morainic deposits of a piedmont glacier.

1 (ii) PREVIOUS WORK

A departure from normal procedure is made by discussing previous geological work in the area at the end, rather than at the beginning of this report. Only a cursory reading of Newell's * report was undertaken before embarking on the expedition and it may be fairly stated that the area was entered "blind" and with no pre-conceived ideas of the structure or stratigraphy.

* "Geology of the Lake Titicaca region, Peru and Bolivia" by N.D. Newell Geological Soc. of America Memoir 36.

1 (iii) FIELD METHODS

The Expedition was in the field for just over five weeks, from July 17 to August 23, and during this period a total area of approx. 370 square miles was examined by the three geologists. The area examined is enclosed by lines drawn between Poto in the N. West, Pinuni in the S. , the eastern end of L. Cololo and the Soral Este peak in the east, and Sina Pass in the north. A traverse was made down Sina Valley almost to the village of Sina. (Map 1).

Exposure varied considerably within the three topographic regions. The sandstone scarps in the west were well-exposed on steep faces, but on gentler slopes were generally covered with soil and moraine. The central areas surrounding and including the pampa were covered by a continuous blanket of moraine and lake deposits. Best exposure was found in the mountain region, although here again moraine tended to clothe some of the gentler slopes and valley bottoms whilst the highest parts were clad by snow and ice.

Because of the monotony of the rock type (hardened shale and quartzite) and the absence of fossils (only three, poorly-preserved brachiopods were found during the whole period) an early decision was made to concentrate on structural mapping. In the field, the oft-experienced difficulty of distinguishing bedding from cleavage was usually to be resolved by the presence of thin silty laminae; or by the refraction of cleavage through beds of different composition.

Linear structures comprised: a) cleavage-bedding intersections b) minor fold axes c) "rodding" in the argillaceous rocks d) boudins e) slickensides.

The "rods" were thought initially to be fragments of more siliceous sediment which had been 'rolled' by fold movements. Perhaps they represent hinges of minor folds. Boudins had been produced by the stretching of quartz veins and of quartzite beds, in both cases these being enclosed by less competent shaly material. A related feature was the disruption of thin beds of sandstone in the alternating shale-sandstone facies.

Readings were occasionally taken of the ubiquitous quartz veining and of joints (Stereogram K). Many joint-readings were made in the extreme east (sub-areas 13 - 15), from which it has been found that glacier flow directions depend largely on the jointing of the rock. (N - S faults probably provide an additional control).

1 (iv) <u>THE MAPS</u>

Planar elements and faults are indicated on Map 1, overturned beds being shown by a hooked arrow. This overturning is based mainly on the criterion of bedding being steeper than cleavage and was confirmed by current bedding S. of Ananea. Two general cases invalidate this criterion - the sagging nose of a recumbent fold (i.e. a downfacing structure) and the development of a second fold cleavage in inverted beds. No evidence was found for either of these cases. Axial traces on Map 1 are based partly on field observation and partly on the evidence of dip arrows. No distinction has been drawn between slaty and fracture cleavages.

Twenty-two sub-areas have been established for stereographic analysis, since it is found that by such sub-division the variations in cleavage dip and strike may be explained.

SUCCESSION AND LITHOLOGY

2 (i) SEDIMENTARY ROCKS

Broadly speaking, a Quartzite Series in the east is separated by a central Argillaceous Series from a Sandstone Series in the west. The rocks are found to become younger westwards. A tentative succession has been established and is given in Table 1.

In the Soral Anticline and to the S.W. of the Azucarani Glacier, the rock is dominantly a fine-grained grey quartzite in beds of 1 - 20 feet thick, separated by subordinate argillaceous material in beds generally less than 4 feet thick. The quartzite is fine-grained,

TABLE 1.

	Rock type or formation	Distribution by Sub-areas
SANDSTONE SERIES	(Upper white sandstone	South 19, W20 above thrust
	(Purple shale and mudstone	Central 19
	(Purple Quartzite	N19, both sides of thrust-20
	(Lower white sandstone	E20 below thrust, 21, 22.
	(Alternating shales & thin sandstns.	Nr. Pinuni, S.W. of Suches village
Unconformity ?		
ARGILLACEOUS SERIES	Rubbly grey micaceous sst.	West 16
	(Alternating shales and thin ssts.	E16, W17, N18, Part 5,6,7
	(Grey cleaved mudstones and poor slates	2,3,4,W6,18,W9,W10
QUARTZITE SERIES	(Fine-gr. sst., grey quartzite, flaggy siltstone	E9, E10,11,12,1.
	(Alternating quartzite and subordinate shale	13,14 ,15.

massive and locally micaceous. The shaly rocks have been given a fairly good cleavage which is mechanical (fracture cleavage) in some cases and true slaty cleavage in others. (Throughout the whole area studied, cleavage was in general on the borderline between fracture cleavage and true slaty cleavage. The term "poor slate" will be used to signify a hard, fairly compact rock which is slightly tougher than the rock type designated "cleaved mudstone".)

In the region of L. Chucuyo Grande and extending to the E. end of L. Suches, argillaceous material is less abundant than on the Soral Ridge and the rocks are dark grey siltstones, often laminated and flaggy; and fine-grained grey quartzites. Probably to be correlated with these are the blue and grey fine-grained sandstones of the northern part of Sina Valley (sub-area 1). These, too, are occasionally laminated. Passing westwards along both northern and southern shores of L. Suches, the grey quartzites become interbedded with argillaceous material and the beds of the former decrease in thickness and interval as the beds of the latter increase. By the time the large N-S valley on the N. Shore has been reached, the lithological facies has changed completely and comprises grey, well-cleaved mudstones with only rare indications of bedding in the form of occasional thin silty bands. The latter appear as thin, lighter-grey laminations up to ¼ inch wide.

In similar fashion, the fine-grained sandstones of the lower part of Sina valley are succeeded by dark-grey and blue-grey cleaved mudstones and poor slates. These have a very extensive outcrop, being found in the upper parts of both Sina and Trapiche valleys, on Sina Pass itself, in the broad area between Sina Pass and L. Cochahuma; and in the eastern halves of the two E-W valleys south of the Pass and extending over the col to the Palomani Lakes. The passage by alternation is not seen.

In the central part of the more southern E-W valley south of Sina Pass, a different lithological facies is seen. This consists of dark-grey cleaved mudstones with interbedded thin sandstones (2" - 6"), the latter occurring at intervals of 18" - 24". The lithological facies and structure (Chevron folding) here are strongly reminiscent of those found in the Culm Measures along the N. Devon coast of S.W. England. In addition to the area mentioned, the alternating shale-thin sandstone facies outcrops at several other widely-spaced localities. Thus it is found at the eastern end of L. Cololo, below the thrust about 2 miles north of L. Suches, around the small lake to the S.W. of Ananea and underlying the Lower White Sandstone both near Pinuni and about 2¾ miles S.E. of Suches village . (On lithological grounds, there is no reason to distinguish the alternating facies beneath the L. White Sandstone from similar facies elsewhere. However, the field junctions in the former occurrences were always conformable and since an unconformity beneath the Sandstone Series is postulated on the basis of differing fold styles, the alternating sequences mentioned probably belong to the younger series.)

A yellow-spotted green tuff was found in the N.W. corner of sub-area 6 interbedded with dark-grey poor slate.

About 1½ miles north of the lake shore, capping a hill on the western side of the valley which leads from L. Cololo to Pelechuco, a 12 ft. thick outcrop of pillow lavas was seen. This was composed of a purplish, fine-grained igneous rock, individual pillows being from 1 - 6 ft. in diameter. The lava rested on a laminated, current-bedded tuff up to 2 ft. in thickness from which a rhynchonellid was obtained. Underlying beds displayed the Shale-thin sandstone facies.

¾ mile W.S.W. of the pillow-lava exposure, the Shale-thin sandstone sedimentary facies passes conformably upwards into at least 300 ft. of rubbly, grey-brown micaceous sandstone. Perhaps this may be tentatively correlated with a thin formation of purple-brown sandstone found ½ mile from the northern shore of L. Suches in sub-area 7.

The Lower White Sandstone is exposed in the prominent N.E.-facing scarp between the western ends of L. Suches and L. Cololo. At least 850 ft. (true thickness) are seen here. Approx. 8 miles to the W.S.W. it again comes to the surface, rising abruptly from the pampa to form three isolated 300 ft. hills. The formation is found, too, along the lower slopes of the N-S ridge to the W. of Rio Trapiche. Lithologically, it is a medium to coarse-grained sandstone varying in colour from white to light brown or grey. It may be flaggy, or massively-bedded, is usually well-jointed and has usually suffered much leaching so that iron-staining exhibits all gradations up to a rich red-brown colour. Many of the larger grains are exceptionally well rounded. A formation of Purple Quartzite rests conformably on the L.White Sandstone and is most extensively developed in the northern part of the range of hills south of Pampa Blanca. It is also exposed on both sides of the N-S fracture to the W. of Rio Trapiche and may also occur about 2 miles N.E. of Cailloma. The rock is pale-purple in colour, fine-grained and well-bedded. Current-bedding, as in the case of the L. White Sandstone, shows the sequence to be the correct way up.

Between the Purple Quartzite and the Upper White Sandstone, a 50 ft. (minimum) bed of well-cleaved Purple Shale is found in the hills to the S. of Pampa Blanca.

The U. White Sandstone is lithologically very similar to the L. White Sandstone, being fine to coarse-grained, hard, sometimes blocky and with variable amounts of iron-staining. It outcrops in the southern part of the hills S. of Pampa Blanca and above the fracture to the W. of Rio Trapiche. It is at least 300 ft. thick.

The observation of ripple marks, current bedding and Chondrites impressions (radial grooves produced by worms), the last being no less abundant than those produced on tidal flats at the present day, suggest that the Lower White Sandstone was deposited in very shallow water. In addition, the extreme paucity of fossils (only one brachiopod ? was found) further suggests rapid deposition of sediment and/or leaching, and with the roundness of the larger sand grains combines to give a mental picture of shallow-water off-shore deposition with occasional influxes of wind blown desert sand.

2 (ii) INTRUSIVE IGNEOUS ROCKS

Two igneous intrusions were found. The first was a small, highly-weathered, dolerite dyke in Sina valley 2 miles north of Sina Pass. It was parallel to the regional strike and approximately vertical.

The second intrusion was a pear-shaped boss $\frac{3}{4}$ mile W. of L. Cochahuma. It had deflected the cleavage and bedding of the slaty country rock. Its dimensions were 1 x $1\frac{1}{2}$ miles. In thin section the rock is seen to be a much-altered diorite. A little lead mineralisation occurs in joints.

2 (iii) MINERALISATION

A noteworthy feature of the mountain area is the occurrence of quartz veins in every rock type. Within the quartzite and alternating quartzite - thin slate facies, these veins are controlled largely by joint planes and are also frequently found between separate boudins where boudinage is developed. In addition, quartz "sweat-out" has contributed largely to the production of Ptygmatic folds seen, for example, at the E. end of L. Suches. In argillaceous rocks, quartz is to be seen between and parallel to cleavage folia (often sharing the secondary deformation of these folia) and in irregularly sub-parallel joints. On occasion, a fairly thick (up to 1 ft.) quartz vein itself displayed boudinage.

An iron-rich carbonate frequently occurs with the quartz, imparting a brown stain to that mineral. Small amounts of chalcopyrite and pyrite may also be associated; whilst in a very few instances a greenish micaceous mineral (chlorite?) was found.

Siderite, in the form of a fresh unaltered mineral, or altering to brown iron oxides may occur with quartz as noted above. In other localities it was the dominant vein filling and in yet others it was found entirely on its own. At a locality S. of Sina Pass, siderite formed the 10 ft. core of a vein bordered by two feet of quartz and the hanging and foot walls.

The only veins studied of economic importance were those of a disused gold mine (the San Antonio Mine). Four principal vein sets are seen, of which three are barren. The fourth has an average width of 1½" and contains, in addition to native gold, a little chalcopyrite, galena and pyrite. Malachite is secondary after the chalcopyrite. The host quartz is either white or a waxy grey. After being mined by hand, the quartz is crushed in a small mill and the fragments panned. It appears that the sulphide-bearing part of the vein has been intruded into a reopening of a previous quartz vein.

Pyrrhotite was the only mineral found which was not related to the silicification. In this occurrence referred to, the pyrrhotite took the form of a discontinuous band of minute crystals in the bedding-planes of a poor slate found north of the Soral ridge. It was probably a late-stage replacement along the bedding planes.

At Suches Mine, a low grade gold deposit has been worked intermittently since 1700 when it was first worked by the Spaniards. The gold is disseminated in a very thick deposit of glacial moraine (perhaps 500 - 600 ft. thick) derived from the mountains to the east. Darker bands in the moraine (representing a more argillaceous source) are the richest in gold. Bismuth, lead and silver occur to a much lesser extent. Initial concentration of the gold is effected by washing the moraine through a channel which has basal riffles. The concentrate is then panned.

The remaining mineral occurrence of note was a band of massive haematite and limonite found in the Sandstone Series $\frac{3}{4}$ mile N.W. of Finca Aurora. Unfortunately no positive outcrops were found; but the float covered an area of 300 yds. x 30 yds., parallel to the strike of the sandstones.

2 (iv) METAMORPHISM

A very low grade of metamorphism is shown by the rocks to the east of L. Suches and in the L. Chucuyo Grande area. The fine-grained siltstones have been compacted and have produced chlorite on a small scale to become impure micaceous quartzites. Cleavage at the same time becomes less pronounced. Siliceous rocks exhibit low degrees of recrystallisation. The most noticeable feature is the migration of quartz into "sweat-out" veins, which are found in most rock types and which also serve to indicate that some of the argillaceous rock facies were more siliceous than others.

It is not known whether the slight increase in metamorphic grade to the east is to be related to stronger folding pressures or to a combination of these with greater depth of burial.

PHYSICAL GEOLOGY

3 (i) TOPOGRAPHY AND STRUCTURE

Only in the western sandstone areas could topography be used as a successful aid to interpreting the structure of the rocks. The Sandstone Series to the S. of Pampa Blanca outcrops in a bold, N-facing escarpment. Further south, between Trapiche and Pinuni along the western edge of the pampa, this same series forms a prominent N-S range of hills which gain height westwards to reach approx. 4950 metres (15,300') whilst at the southernmost end of this range three isolated hills rise sharply from the pampa at the confluence of Rio Trapiche and Rio Suches. They mark fold axes within the Sandstone Series. The sandstones then dip eastwards beneath the pampa and for about 7 miles not a single exposure of solid rock is found. In this intervening distance the pampa continues for about 6 miles and then grades upwards into rolling grassy hills of the Moraine Belt. Between the western ends of Lakes Suches and Cololo, the Sandstone Series reappears to form a well-marked N.E.-facing scarp which reaches 4400 m. (14,500ft.).

In the mountainous area to the east, topography is no longer such a good guide to the structure. On the large scale, the watershed of the quartz into "sweat-out" veins, which are found in most rock types and which also serve to indicate that some of the argillaceous rock facies were more siliceous than others.

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In the mountainous area to the east, topography is no longer such a good guide to the structure. On the large scale, the watershed of the mountains runs for part of its course in a N.W.-S.E. direction parallel to the regional trend of the rocks. The Soral, Palomani and Matchu Suchi Coochi ridges also take this alignment, as do the combined ice fields of the Azucarani and West Soral glaciers. It is noticeable that the rivers are either parallel to the regional strike, e.g. Rio Sanchescuchu, or at right angles to it, e.g. Rio Soral. Similarly, the rivers to the S.W. of the watershed are markedly sub-parallel in their upper reaches, all flowing W.S.W. A structural control is postulated for the origin of Lakes Suches and Cololo (Section 4(ii)). It is suggested that antiforms of the second folding were more easily exploited by glaciers than the corresponding synforms.

On the small scale, structures which have exerted a control upon topography are cleavage, bedding and jointing. These three features are variously affected by frost action and sometimes one, sometimes another determines the trend of a particular peak or valley, often without visible change of sediment.

3 (ii) <u>GLACIAL TOPOGRAPHY</u>

Measurements of the flow directions of existing glaciers show them to be largely controlled by the jointing of the underlying rock. A further control is probably to be found in the N-S faulting displayed in some areas. The glaciers are fed from several ice fields, whose altitudes vary, on average, between 17,000 and 18,500 feet. South-flowing glaciers from any given ridge generally extend 1-2000 feet lower than the corresponding N-flowing ones. The absence of a central all-supplying ice-field probably accounts for the disconcerted action of the glaciers for some were retreating whilst others were advancing, both these movements having a rate of 1" - 2" per day.

The overall picture in recent geological time is one of retreat. The Moraine Belt, which was laid down by glaciers issuing from their valleys and coalescing over a wide area (i.e. a piedmont glacier), is now fully clothed by vegetation; and grass is beginning to sprout on the hummocky moraines within the valleys themselves. The glacier which has withdrawn from L. Calijon to Ananea has left in its wake a series of crescentic terminal moraines with intervening lakes and later swamps, whilst lateral moraines form ridges on the sides of the valley at successively lower levels. A similarly-formed feature is a morainic ridge about 500 ft. above the northern shoreline of L. Suches just under 2 miles from the N.E. corner of the lake. It is parallel to the lake and indicates the height of glacier which produced and supported it.

Sina valley, running northwards from the watershed of Sina Pass, displayed many glacial features. It was U-shaped in cross-section and sensibly straight for a distance of about 10 miles. The flat-lying valley floor descended in three pronounced steps to the north (Fig. 2). One of the flat stretches may have been the site of a small lake held back by a land slip. The three steps, however, probably had a glacial origin, for which the commonly-held theory invokes corrie-action by residual fragments of the valley glacier. In the lower reaches, Rio Sina meandered among interlocking spurs produced in 10 - 20' of alluvium and moraine. This valley-in-valley form modified the U-shaped cross-section (Fig. 1).

Asymmetrical folding at the eastern ends of Lakes Suches and Cololo

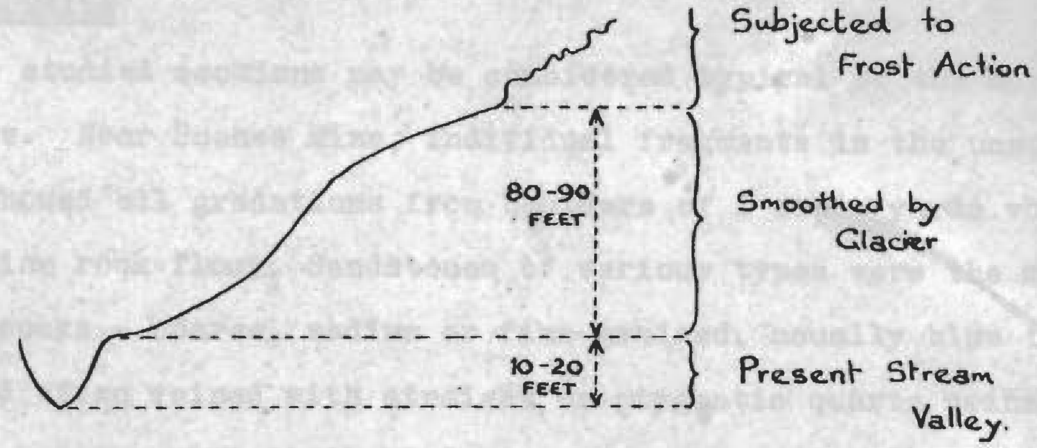


FIG. 1. CROSS-SECTION, N. END OF SINA VALLEY.

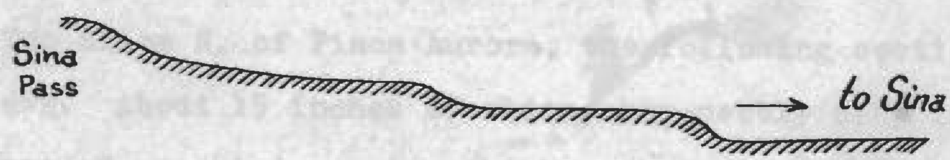


FIG. 2. DIAGRAMMATIC LONG.L. PROFILE OF SINA VALLEY.

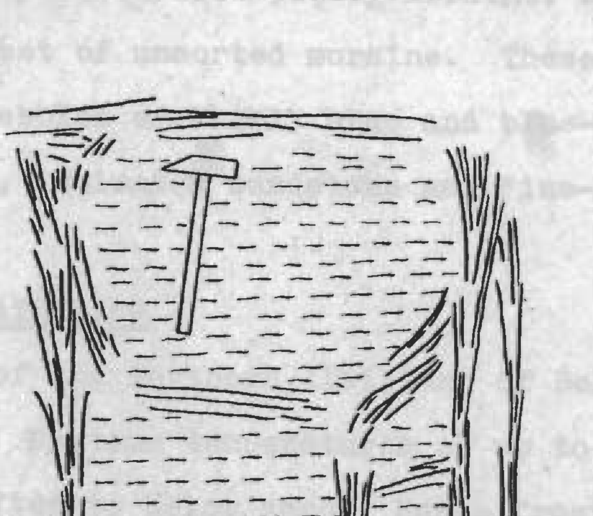


FIG. 3. STREAMING IN SHALE

3 (iv) MORAINE

Two studied sections may be considered typical of the moraine as a whole. Near Suches Mine, individual fragments in the unsorted deposit showed all gradations from boulders of 2 cubic yards volume down to fine rock flour. Sandstones of various types were the most abundant rocks - coarse, medium or fine grained, usually blue in colour and often veined with straight or ptygmatic quartz veins. Quartzite was the next most abundant rock type, followed by vein quartz and then shaly rocks and phyllite. In general, the boulders were well rounded. Their matrix consisted of clay minerals and rock flour and contained gold, bismuth, lead and silver.

Two miles N. of Finca Aurora, the following section (Fig. 4) was drawn. About 15 inches of white, non-pebbly clay is underlain by 7 feet of unsorted moraine which contains blue sandstone and poor slate, grey quartzite and vein quartz. Overlying the clay is some 4 feet of poorly-stratified pebbly moraine, which is succeeded upward by about 8 feet of unsorted moraine. These last two sub-divisions contain pebbles of khaki, blue and blue-black siltstone, micaceous siltstone, laminated sandstone and fine-grained grey quartzite.

3 (v) SOILS AND WEATHERING

The rainfall of the Northern Altiplano of Bolivia varies from 16 - 27" per annum. Daytime temperatures of up to 60 - 70° drop sharply at night, often to below zero. Hence frost action is a prominent weathering agent and, depending on the cleavage and jointing of the rock, produces angular blocks (sandstone) and flakes or

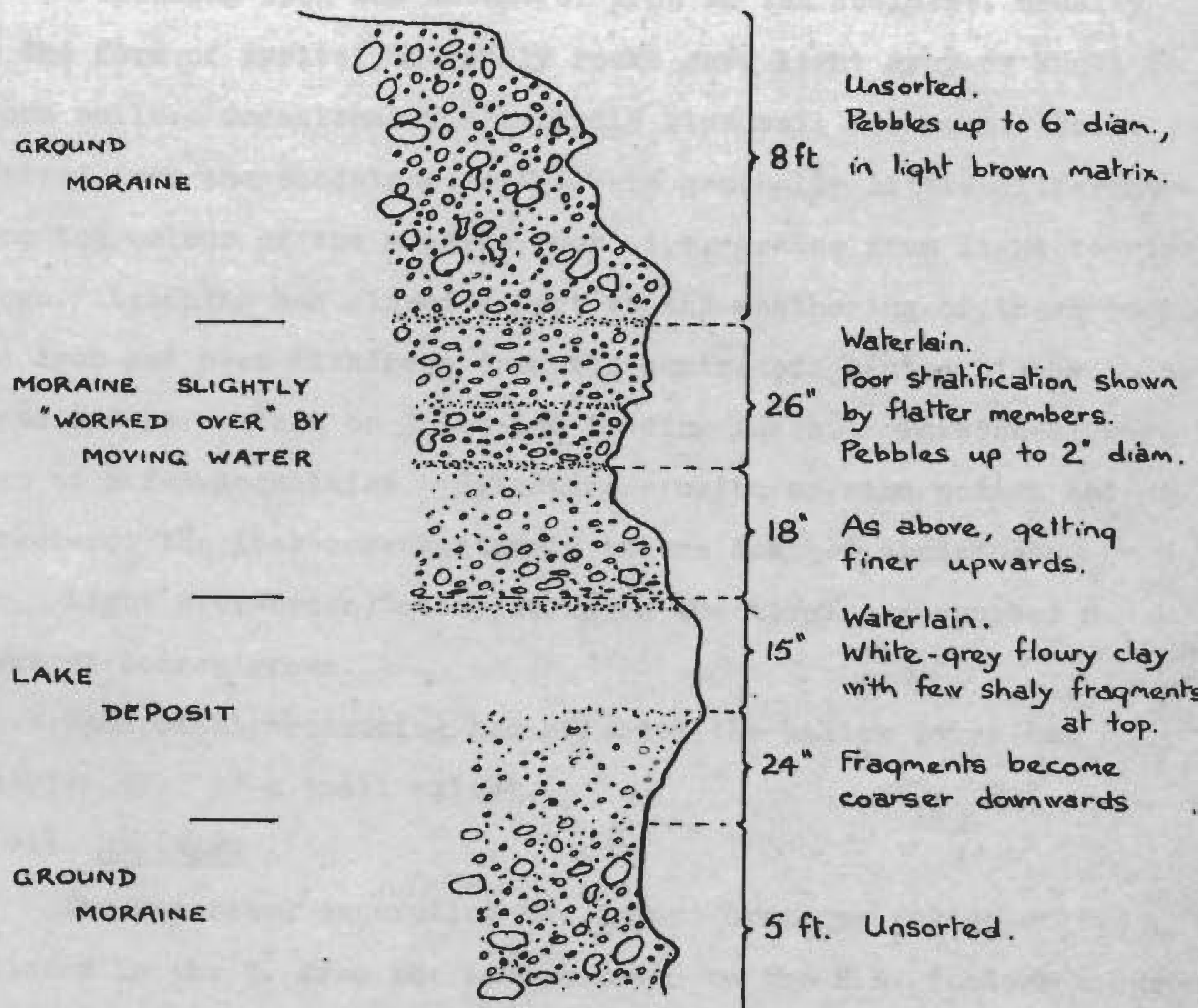


FIG. 4 TYPICAL SECTION FROM THE MORAINE BELT.

pencils (shale). Extensive scree slopes were often to be found, e.g. along parts of the Sina valley where they reached 150 - 200' above the valley floor.

Depending upon the amount of iron in the sediment, usually in the form of pyrite, the shaly rocks gave light grey or khaki to brown soils. Occasionally a markedly blue soil was seen. Soils derived from the sandstone series were generally little different from the colour of the massive rock, i.e. grades from light to rich-brown. Leaching has played a part in the weathering of these rocks and iron had been withdrawn from the centre of jointed blocks to be deposited as a stain on joint and bedding faces. 'Boxstones' were seen at a few localities. Selective erosion by wind action had picked-out the less-cemented parts of the leached sandstones.

Light grey-brown, stony soils on the moraine supported a cover of coarse grass.

Spheroidal weathering had affected the pillow lavas and dolerite dyke to a small extent.

3 (vi) <u>DRAINAGE</u>

The watershed separating the inland drainage region of L. Titicaca in the S. from the Amazon Basin to the N.E. follows a curve which is convex northwards. It runs from Pelechuco Pass northwards to the Soral Ridge, thence N.W. to Chupi Orco and W. to Calijon over the Sina Pass.

Streams and rivers were everywhere small in volume, largely because of the Season (Southern Winter). In the Summer months, rivers are swollen by melt-waters and the pampa becomes one large marsh, only crossed with difficulty.

The drainage of the pampa follows its southern slope and eventually the rivers combine to flow through a steep-sided valley; the western side, of sandstone, is approx. 100 feet high; the eastern side which forms part of the Moraine Belt is less steep. Thereafter the river continues to L. Titicaca.

3 (vii) LAKES AT THE PRESENT DAY

Two convenient catagories may be distinguished: lakes on solid rock and lakes on moraine.

Of the former group, the lakes to the N.E. of and including L. Suches may be taken as examples. L. Chucuyo Grande is fed by numerous melt-water streams from the surrounding ice-cap. It occupies a rock basin, steep-sided in many places, from which it overflows to L. Chucuyo Chico in a waterfall. Probably the lower lake was once deeper and rather larger, at a time when the W. Soral glacier had greater lateral extent. The former outlet would be down the Pucar Kollo valley immediately south of San Antonio mine. Two shallow, almost circular rock basin lakes occur E.N.E. of L. Suches. The lower of these is an indirect result of the glacial plucking mentioned in Section 3 (ii).

Lake Suches itself is long and probably quite deep. It rests in a glaciated valley, of which the eastern third is of solid rock and blunt-ended. To the west, the valley-sides slope gradually downwards, decreasing from over 1,000 feet to less than 50 feet at the mouth of the lake, where moraine has entirely blanketed the solid rock. The outlet is shallow, boulder strewn and about 50 yards wide. Practically identical conditions characterize L. Cololo.

Draining into the western part of L. Suches is a string of four Paternoster lakes (termed the "Palomani Lakes"). Their waters rest on the flat stretches of a stepped, glaciated valley (Cp. Sina Valley).

The second category of lakes - those on moraine - is exemplified by an unnamed lake on Pampa Blanca which drains west through Poto. Its basin is wide, shelving and shallow. Many of these "over-sized puddles" are to be found in the wide expanse of the Moraine Belt, but they are usually inconstant and readily dry-up in the (Southern) Winter months of July to November.

3 (viii) <u>FORMER LAKES</u>

One of the most difficult problems encountered concerned the origin of the "pampa", that extremely flat tract of country, poorly-drained by small streams, which has an areal extent of about 200 square miles. From near Trapiche in the north, it slopes very gently S.S.E. to beyond Ucha Ucha, a distance of approx. 30 miles. The maximum width of 10 miles opposite L. Cololo decreases southwards until the western boundary of solid rock meets the eastern boundary of moraine; and here the entire drainage of the pampa in the form of a shallow river flows through a steep-sided valley.

Almost certainly the flatness and low slope (1 in 160 or $3^{o}35'$) can be attributed in one way or another to water. Aggradation by fluvial sediments had been the dominant process in recent geological time, but it is possible that a degraded topography (i.e. a marine planation surface) underlies the pampa.

The first stage of formation, as suggested here, requires a great enlargement of the mountain ice cap and the smothering of existing topography beneath a thick blanket of moraine. On the partial retreat of the ice, it is considered that an extensive lake remained, impounded by solid rock and moraine in the south and by piedmont ice in the north. Outwash streams would thus have no opportunity of eroding the unconsolidated sediment. They would be compelled to drop their load in the lake, tending to build a flattish floor. The fact that streams of the area begin to meander before reaching the pampa accords with this conception of a local base-level.

When the lake eventually drained (to the South) the great extent and relative flatness of its basin did not permit a rapid erosion. Rather did it slow down the streams and induce greater meandering. Establishment of a vegetation cover of wiry grass and marsh plants further holds the soil and probably contributes to aggradation by catching wind-blown dust.

The following stream section (Fig. 5) was sketched 1¾ miles S.E. of Suches village. It shows lake deposits of fine grey clays above and below a central, discontinuous pebble deposit. This last probably represents an old watercourse. The two thin clay-and-peat bands presumably indicate one-time marshy conditions.

In the field, the flat tops of a number of the moraine ridges was thought to indicate deposition below, but near, water-level. If this were the case, a subsequent lowering of lake-level would have to occur almost to the level of the present pampa.

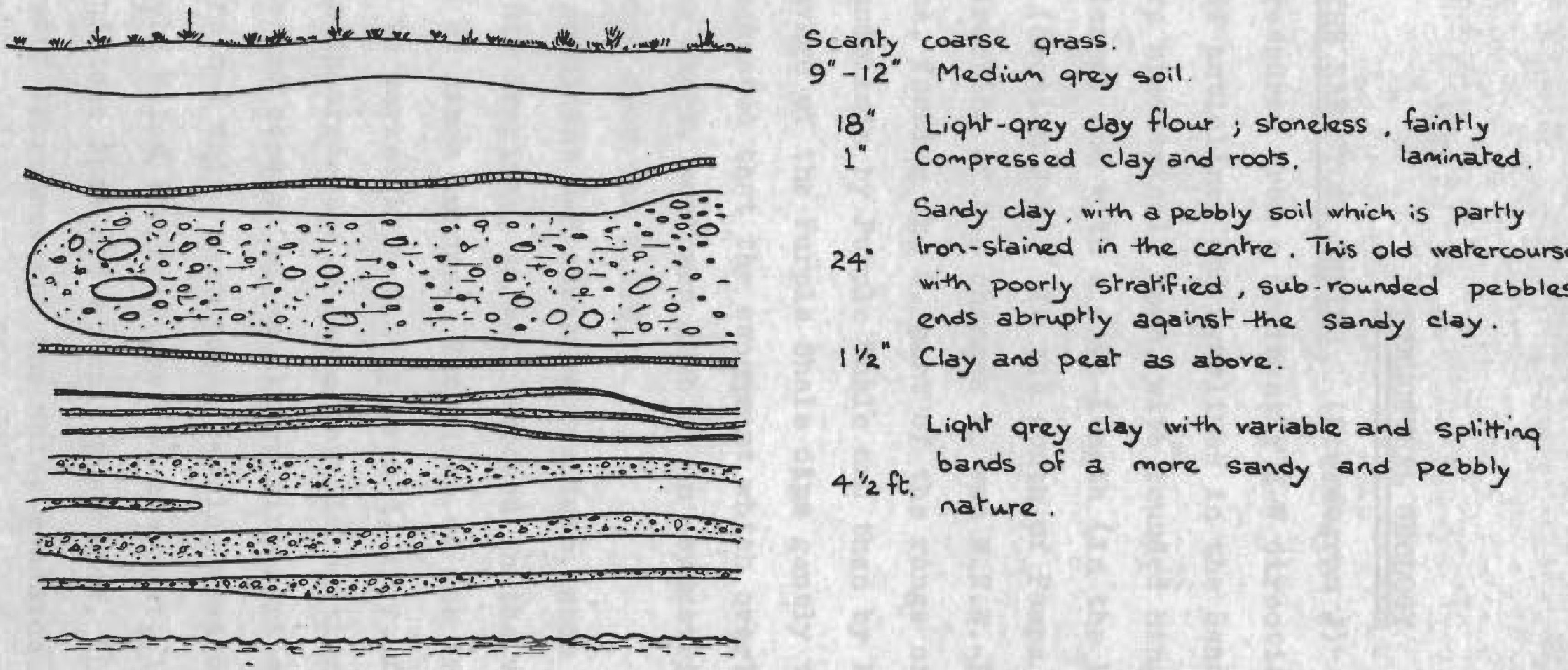


FIG. 8. STREAM-SECTION OF MARGINAL LAKE DEPOSITS.

Iron-stained tubes of roots in their position of growth are found throughout the section. They are most prominent in the bed beneath the soil and in the lowermost beds. Maximum diameter of tubes = 1/4 inch.

STRUCTURAL GEOLOGY

4 (i) THE SANDSTONE SERIES (Stereogram J)

Pressures from a dominantly E-W direction have produced a series of anticlines and synclines in the Sandstone Series. These folds are symmetrical, open, with rounded hinges and vertical axial planes; and with a wave-length (in the Pinuni area) of approx. 3 miles (Section J-K). To the south of Pampa Blanca the usual axial trace direction of N-S changes to run W.N.W.-E.S.E. Here, the U.White Sandstone, forming the S. part of the range of hills, dips gently S.W. and is underlain by Purple Shale and then by Purple Quartzite. Since the cleavage of the Purple Shale dips gently towards the N.N.E., it is suggested that the escarpment which overlooks Pampa Blanca forms the short, southern limb of an asymmetrical fold which has been pushed from the N.N.E.

A prominent N-S striking fracture, some $\frac{3}{4}$ mile to $1\frac{1}{2}$ miles west of Rio Trapiche, is well exposed in the valley immediately to the west of Finca Aurora. The plane of the fracture dips to the west and is marked by a finely-ground, grey, flinty rock, underlain by a wide sheared-zone. Above the dislocation, beds dip gently eastwards and consist of an alternating series of fine-grained and coarse-grained white sandstones passing upwards into purple sandstones. Immediately below the fradture, to the east, is a well-bedded coarse white sandstone inclined steeply westwards, whilst further to the east the dip decreases and the white sandstone appears to be underlain by purple sandstone. Another strongly-sheared flinty rock to the S.W. of Trapiche stock farm probably indicates the northward continuation of the fracture.

An E-W fault with downthrow to the south is found in the sandstone scarp to the E. of the pampa.

The folds in the Sandstone Series are quite different from fold styles seen further east in the mountains. This may indicate different reaction to the same pressures. (No angular unconformity or basal conglomerate was seen in the field between the sandstones and underlying shales, but it is probable that the shales immediately beneath the sandstones are also part of the Younger Series.) The fold styles are sufficiently different to warrant the assumption of an unconformity, whilst if the N-S fracture is indeed a thrust, as was thought in the field, dominant pressures must have been from the west and hence completely opposite in direction to pressures in the eastern area.

4 (ii) THE QUARTZITE AND ARGILLACEOUS SERIES

In the eastern mountainous area, folding pressures came from the N.E. and have produced styles of folding which depend to a large extent on the lithology of the rocks concerned. The sandy and quartzitic rocks of sub-areas 11 - 15 and 1 reacted to the strong compression by producing folds which often have very steep limbs. In general they are symmetrical or slightly overturned and the cleavage dips between 50° and 90° to the N.E. (Sections A-B, E-F). Further to the S.W., as argillaceous rocks become increasingly dominant, the fold style changes in sympathy. The poor slates of Sina Pass are isoclinally folded (Section A-B); whilst alternating shales and thin sandstones at Lake Cololo exhibit asymmetrical folds, again overturned from the N.E. (Section G-H). In both these areas, cleavage dips 30° - 50° to the N.E. In sub-areas 4,5,6 and 8, where the rock type is almost exclusively cleaved mudstone and poor slate, the variation in cleavage dip is taken a stage further. In these areas it is very low and dips at less than 30° to the N.E. (Section C-D).

The variation just noted indicates that the direction of easiest relief (the a stress axis) was upwards in the east, but that further west it inclined increasingly over to the S.W. as the compressive forces acted on more argillaceous rocks. Put in another way: the dip of the cleavage decreases progressively from E. to W.

The variation in cleavage strike, as opposed to the dip variation, is not considered to be an effect of the primary folding. Rather is it due to a second phase of folding much weaker than and at right-angles to the first, i.e. pressures acting in a N.W.-S.E. direction. Thus in sub-area 2, the cleavage has the regional strike of 150°. To the north, in sub-area 1, the strike swings to 140°, whilst to the south, in sub-area 3, it swings in the opposite direction to 160°. The linear structures change their plunge direction in sub-area 2, dipping away from it on both sides. This culmination indicates a gentle warp of the controlling cleavage planes about an axial plane striking 060°. Although the Sina Pass and Sina Valley areas have been taken as an example, the same pattern - of regular deviation from the regional cleavage strike accompanied by corresponding culminations and depressions in the plunge of much more quartz veining than further north. The presence in this area of a greater number of silty bands in the rock may explain this feature. The quartz probably migrated ("sweat-out") in response to the extreme pressures of folding. Between the Pass and L. Calijon, no indications of bedding were to be found in the poor slaty rocks. The dip here is very low (less than 30° to the N.E.) and the strike very variable.

Commonly in the areas just described and in other areas where slaty rocks are developed, the cleavage folia have been sharply bent by subsequent movements. The deformation shows itself as small-scale angular corrugations, the axes of which were measured in the field as linear structures. Such lineations are found to be approximately parallel to the calculated axis of the local fold and may therefore represent a late phase of the first folding.

4 (ii) B. <u>SOUTH OF SINA PASS. THE "PALOMANI LAKES".</u> (Stereogram B)

Grey cleaved mudstones outcrop in the eastern parts of sub-areas 5 and 6, whilst the Shale-thin Sandstone facies is found in the central and western parts, especially in the centre of the southern-most E-W valley. In both areas the cleavage dips at a low angle, usually below 30° and its strike is very variable. At the western end of the possible E.N.E.-W.S.W. fault, a 10 ft. thick breccia of quartz and siderite separates overlying beds striking 276° from underlying beds with a strike of 352°. This fact, plus the juxtaposition of flat-lying and much steeper cleavage along the boundary between sub-areas 3 and 5 suggests that a N.E.-S.W. structural break occurs here. It is not shown on the map.
The prominent chevron folding (with limb-length approx. 40')

found in the central part of the valley and along the eastern side of Trapiche Valley has been affected by the second folding, so that the axial planes, which were probably at one time horizontal, now dip gently to the S.E. Likewise the linear structures have been affected and show a variety of plunge directions although most plunge either to the S.E. (down the dip of the axial plane) or to the NW

To the S.E. of the Palomani Lakes, a N-S thrust which dips eastwards at 40-50° is seen as a well-marked fracture in the valley side. This fracture runs diagonally up the eastern valley wall to the south and can be traced further south to within ½ mile of the N. Shore of L. Suches - a total distance of about 3¼ miles. In the extreme west of sub-area 8, at the headwaters of the stream draining south to L. Suches, the thrust is marked by a 15 foot vein of iron-stained quartz which dips eastwards at 55°. It is here downthrown to the south by a small fault striking 212°, which also displaces a previous fault striking parallel to the thrust at 190°.

The outcrop of the thrust in the moraine-covered area is marked by a line of iron-stained quartz boulders. Opposite the circular Palomani Lake in the north, a second fracture breaks off from the first, whilst two converging lines of quartz boulders in the south indicate the southern limit of this splinter thrust. An extensive, but isolated, outcrop of breccia S.W. of the circular lake may represent yet another splinter-thrust.

4(ii) C. EASTERN END OF L.SUCHES. NORTHERN AND SOUTHERN SHORES (Stereogram C)

The grey quartzites and siltstones of the eastern parts of sub-areas 9 and 10 are folded into asymmetrical anticlines and synclines

The long limb of the anticline dips E. to E.N.E. at 10°-30°, whilst the short limb dips steeply to the W.S.W., or is vertical, or dips steeply to the E. (overturned) (Section E-F). The cleavage usually dips about 30° to the E, changing its strike between the two sub-areas.

The asymmetrical style of folding continues along the southern shore of L.Suches, probably as far as Caljiapata, but on the northern shore the fold style is difficult to determine until the most eastern N-S valley is reached. Here, the dip of the bedding (at localities where readings were made) was always greater than the dip of the cleavage, indicating that the beds were overturned. Likewise, in the valley to the west, bedding was always steeper than cleavage, both dipping to the E.N.E. Two interpretations are possible: 1) That the structure of the two valleys is that of the inverted limb of a large recumbent fold; 2) That the folding is a continuation of the fold style further east (i.e. asymmetrical folds) modified by a slightly greater fold wavelength and a flatter cleavage dip (Section C-D). In this interpretation, field readings must have been confined almost entirely to the steeper, overturned limbs. It is not considered that the rocks are isoclinally-folded since there exists a large angle between bedding and cleavage.

The thrust plane in the west dips beneath the asymmetrical folding and probably lessens in dip to the east. It separates steeply-dipping, overturned beds above from underlying beds whose structure is not completely known but appears to be asymmetrical and similar to the folding at Sina Pass.

Nothing is known about the movement on the thrust plane, but it is suggested here that only a small translation has occurred: the grey and blue-grey cleaved mudstones of sub-area 8 "tie-in" neatly with similar rocks at Sina Pass when traced along the regional strike, whilst a sub-thrust facies of alternating shale and thin sandstone "ties-in" with a similar facies in sub-area 6.

4 (ii) D. PELECHUCO PASS AND L.COLOLO (Stereogram D)

On Pelechuco Pass, a series of grey quartzites with intercalated shales is found, similar to the facies observed near the eastern end of L.Suches. This series is flanked to the east, down Pelechuco Valley, and to the west by overlying dark-grey to black shale, whose cleavage has the regional strike. The structure of the Pass is thus a broad N.W.-S.E. trending anticline. The fold is roughly symmetrical in the S.E., but is asymmetrical in the N.W., its short limb dipping steeply to the S.W., or vertical, or even slightly overturned.

At the eastern end of L.Cololo, asymmetrical folds whose axial traces strike 155° are overturned from the N.E. The cleavage dips on average 30°- 50° to the N.E. It is interesting to note that the gently-dipping limb of the anticlines has been pushed beyond the horizontal, so that it now dips to the S.W. The practical effect of this arrangement is that beds become progressively younger to the west. (Section G-H). Further to the west, the long anticlinal limbs are inclined to the N.E. The wavelength of folding in this region varies between 300 yards and one mile and is thus smaller than that of folds further north (Pelechuco Pass and L.Suches).

4 (ii) E. THE SORAL RIDGE AND RIO SANCHES-CUCHU VALLEY (Stereogram E)

The Soral ridge is situated on the crest of a broad and open anticline (termed the Soral Anticline) which is composed of grey quartzite with lesser amounts of interbedded poor slate. The N.E. limb dips at 30°-40°, flattening to become horizontal, whilst the S.W. limb is inclined at about 50° near the cusp-like hinge, decreasing in dip on the flank. The fold-form does not appear to continue in depth. Probably the style of folding is concentric: bedding plane slip would be facilitated by the presence of shaly beds, which would receive a fracture cleavage dipping to the N.E. and to the S.W. on respective fold limbs. Such an explanation would account for the two clusters of cleavage poles on the Stereogram. The Soral Anticline is known to extend for at least 8 miles and probably goes well beyond these limits.

S.W. of the Azucarani glacier in Sub-area 14, two N-S faults run parallel to the valleys which contain them. A N.N.W.-S.S.E. fault parallels the glacier edge and a well-marked W.N.W.-E.N.E. fault cuts the ridge between the two valley faults, probably connects with a similar fracture to the west and perhaps with another on the N.E. side of the glacier in the Rio Sanches-Cuchu Valley. The beds in sub-area 14 dip at low angles and are variable in strike, much of this being due no doubt to the faulting. Their poles, however, (Stereogram E) are only slightly displaced from the great circle on which lie the bedding plane poles of the Soral Anticline. Thus they probably represent the faulted hinge of a similar structure (anticline).

4 (ii) F. NORTH AND N.W. OF MATCHU SUCHI COOCHI (Stereogram F)

This area, covered by sub-areas 11 and 13, extends from the larger N-S fault in the east to the small lake (L.Chucuyo Chico) south of L.Chucuyo Grande. It includes the large glaciated valley leading S.W. from the snout of the W. Soral glacier.

The N-S fault forming the boundary between sub-areas 14 and 13 separated flat-lying beds on the east from steeply-dipping, tightly-folded beds on the west (Section E-F). Very similar, tight folding is seen along the valley below the W.Soral glacier, the limbs of these folds dipping 60°-90° and sometimes being overturned from the N.E. Cleavage dips steeply at 60°-70° to the N.E. Intense folding pressures have probably accentuated the orginal sand-shale sedimentary alternation by causing quartz to migrate into the quartzitic beds. These vary from ¼" to 12" in thickness and frequently display ptygmatic folding.

A prominent fracture (?thrust) in the eastern valley wall cuts N.N.E. across the valley and could be traced S.S.W. for about 1½ miles.

The bedding-plane poles of sub-area 11 (Stereogram F) do not readily fall on a great circle which also contains the cleavage poles. Perhaps it is significant that a small circle drawn 60° from an axis plunging 10°/302° links these poles better. Such a small circle, if it truly represents the style of folding, would indicate conical folding, with the possibility of an unseen unconformity; and the position of the axis would suggest that the deformation took place during the first fold phase. Insufficient data - of planar and linear structures - are available to decide this issue.

4 (ii) G. LAGO CHUCUYO GRANDE AREA (Stereogram G)

Once again, insufficient structural data are available for analysing this region, which is perhaps one of the most complex in the area. It is seen from Map 1 that the cleavage strikes of sub-areas 15 and 13 converge here and in fact the cleavage strike of sub-area 12 is intermediate between the two. Linear structures in general plunge N.N.W., some at angles greater than 30°. Bedding planes dip mainly towards the north, i.e. between 270°-360°-090°; the most noteworthy being the steeply-dipping beds which are inclined towards W.N.W. The latter are unrepresented in sub-area 11, but a few are found to the S.W. in sub-areas 9 and 10.

4 (ii) H. ANANEA TO TRAPICHE STOCK FARM (Stereogram H)

Only two undoubted readings of bedding were obtained in sub-area 18. The first, at the edge of the intrusion near L.Cochahuma, had been affected by the emplacement of that body; the other, S.W. of Ananea, was in a shale-thin sandstone facies and the presence of well-developed current-bedding showed overturning from the north. The widely-present black, cleaved mudstones of the area - phyllitic south of Ananea - bore a cleavage with variable dip and strike. The strike was 140° S.W. of L.Calijon, with N.W. dip; 070° in the vicinity of L.Calijon, with dip to the S.S.E.; and 075° south of Ananea, with a northerly dip. The relation of the last two groups to the structure of the area is not known.

4 (ii) I. SUMMARY AND CONCLUSIONS

A first phase of movements, producing a N.E.-dipping cleavage and folds which are overturned from the N.E., has affected the whole of the eastern part of the area studied. In the extreme east, quartzite with subsidiary poor slates have been deformed in a concentric manner (Soral Anticline). Tracing across the strike to the W. and S.W., folds become asymmetrical, become tighter and become overturned, so that the cleavage dip decreases progressively towards the west. The fold style is now similar. The ultimate of this deformation is the production of chevron folds, with horizontal axial planes and a low-dipping cleavage.

The paradox of finding the most deformed structures furthest away from the generating pressures is explained by considering the lithology. The rocks become stratigraphically younger to the west and in this direction the proportion of argillaceous matter in the sediment gradually increases. Concomitantly, the proportion of arenaceous material and hence of beds which can act competently to folding pressures decreases. The direction of easiest relief (the <u>a</u> stress axis) is steeply upwards in the east, but becomes more and more inclined to the S.W. further west. Whether this last feature is entirely due to the lithological variation is not known: the western parts may have been nearer the surface during their folding than the eastern parts.

Two probable thrusts, an inferred structural break (which may be yet another thrust) and several high-angle faults affect the folded rocks.

Movements at some later date, but again from the N.E., have caused a corrugation of cleavage folia about axial planes to which the local <u>a</u> direction is perpendicular.

The second fold movements were much less intense than the first and at right-angles to them, acting in a direction N.W.-S.E. It is not known from which of these two directions the main pressure came; overturned beds at Ananea show pressures from the N.N.W. which may be those referred to; whilst the beds in sub-areas 9, 10 and 12 which dip steeply to the W.N.W. and N.W. may show the opposite.

The second folding warped the first-fold cleavage, especially where the latter was low-dipping. This cleavage shows regular undulations (in plan) along its strike from Sina Valley in the north to L.Cololo in the south. Associated linear structures show corresponding culminations and depressions over axial traces trending approx. N.E.-S.W.

The Sandstone Series probably lies unconformably on the Argillaceous Series. It has been folded into open anticlines and synclines, which plunge south, by E-W pressures. If the fracture to the west of Rio Trapiche is really a thrust, dominant pressure came from the west.

DESCRIPTION OF ROCK SLIDES

5 (i) CLEAVED SILTSTONE (Rock Slide 1)

Mineral grains are almost exclusively of quartz, with rare grains of fresh oligoclase. The quartz generally gives unstrained extinction. Boundaries between individual particles are sutured and often granulated. Occasional large patches of iron-ore are presumably granulated pyrite crystals. Mica flakes, usually showing a bent extinction, occur in two directions, of which one is much more pronounced. The mica has been largely altered to chlorite. Groundmass of fine grained clay minerals.

5 (ii) QUARTZITE (Rock Slide 2)

Mineral grains almost exclusively of quartz. At least 90% of these grains give a strained extinction and many have trains of small bubbles, suggesting derivation from igneous and/or metamorphic rocks. Occasional patches of iron-staining are found. Shreds of mica occur between the grains as a groundmass and often are "eating into" the grain margins.

5 (iii) SANDSTONE (Rock Slide 3)

Large, well rounded quartz grains up to 1 mm. in diameter are conspicuous in both the slide and hand specimen. They may be fractured on a rectangular pattern, some show strained extinction, whilst a number have curved trains of small bubble inclusions. Smaller, sub-rounded to sub-angular quartz grains surround the larger grains. Many have bubble inclusions and more than 50% give a strained extinction. Rare grains of rounded detrital tourmaline occur. Sub-angular particles of chert are often coated with iron-oxide. Sub-rounded to well-rounded grains of iron-ore occur. In one part of the slide, a mosaic of quartz and chert is found and also a vein of chert.

The groundmass of this slide comprises original sedimentary mica and also authigenic mica, the latter especially noticeable as a fringe to the large rounded quartz grains.

5 ...) ALTERED DIORITE (Rock Slide 4)

...ary essential minerals

Iron ore abundant in anhedral grains up to ½mm. diameter.

Oligoclase - large, fairly euhedral crystals up to 2mm. x 1mm., often closely lamellar-twinned. Only a trace of zoning was seen.

Orthoclase - may be present, but the only marginal felspar with refractive index less than that of Canada Balsam contained crystals of epidote.

Amphibole - non-pleochroic, length slow with Z-C on average 14°. Polarisation colours grey and yellow, up to sensitive violet. Optically negative. The crystals are rather ragged and show no good cross-sections, but one 8-sided section suggests derivation from a pyroxene. Some of the amphibole may be tremolite.

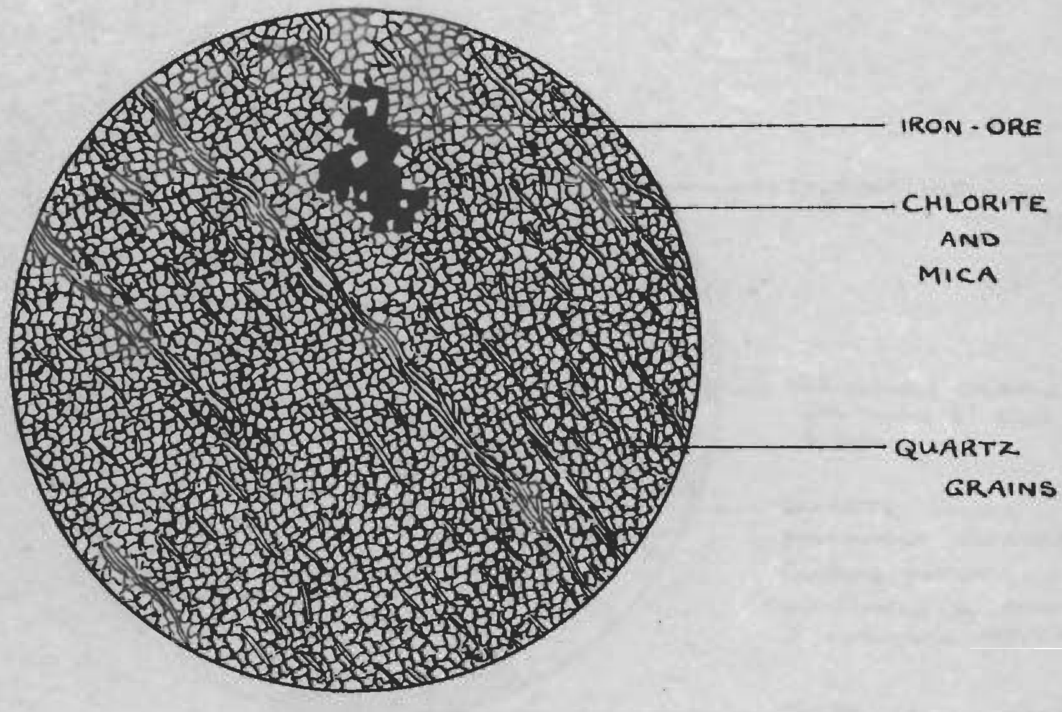
Primary accessory minerals

Apatite - fairly abundant in rounded and elongate sections, latter showing basal fracture, often with the development of sericite and chlorite along it. Usually associated with felspar.

Quartz - a few large patches with an appearance of being later than the rest of the rock. Some are very strained.

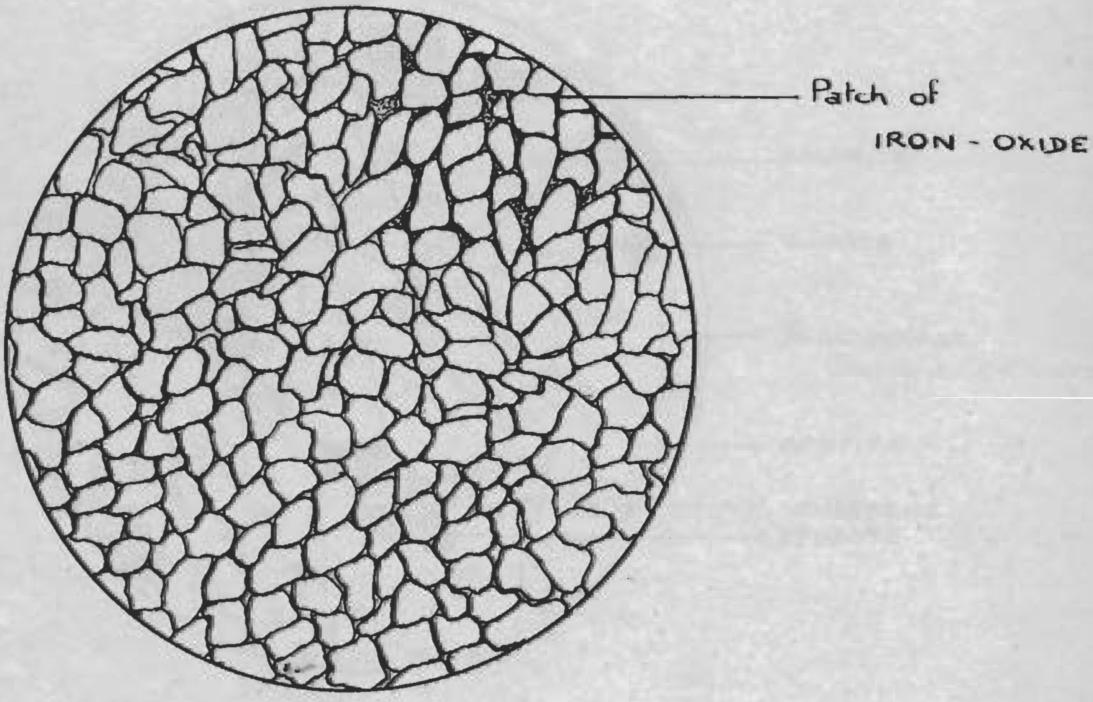
Secondary minerals

Chlorite - abundant and almost completely replacing the amphibole. Anomalous purple-plum coloured polarisation colours. Pleochroic.



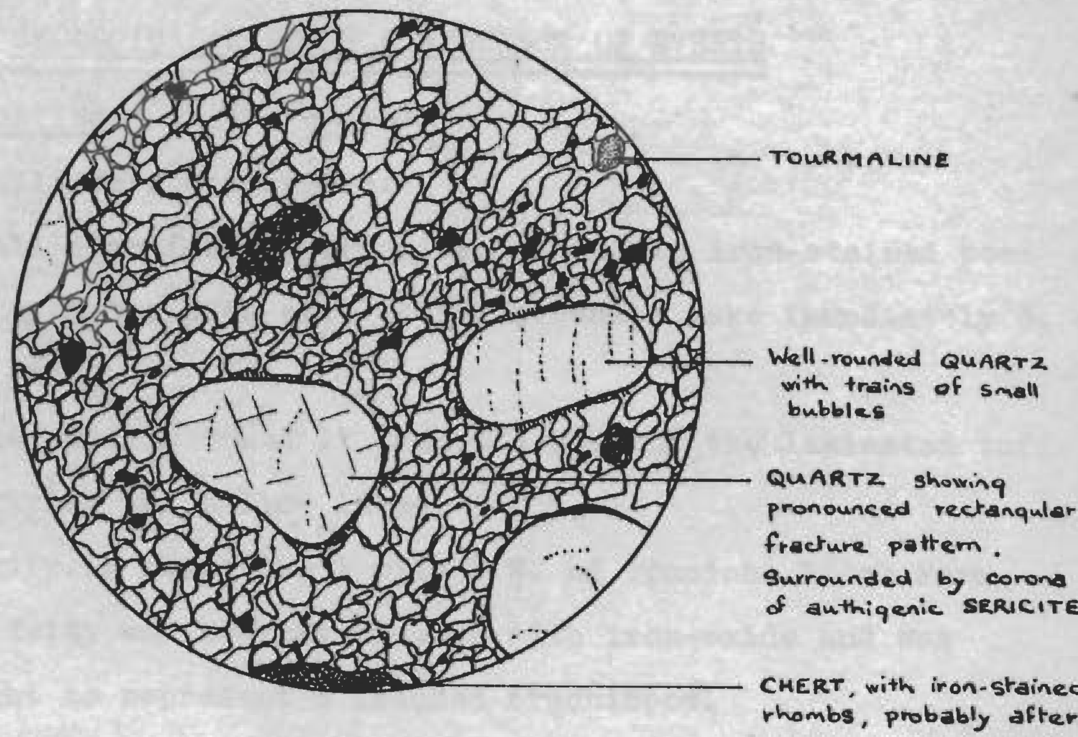
ROCK SLIDE 1. CLEAVED SILTSTONE

Locality :- Pelechuco Pass.



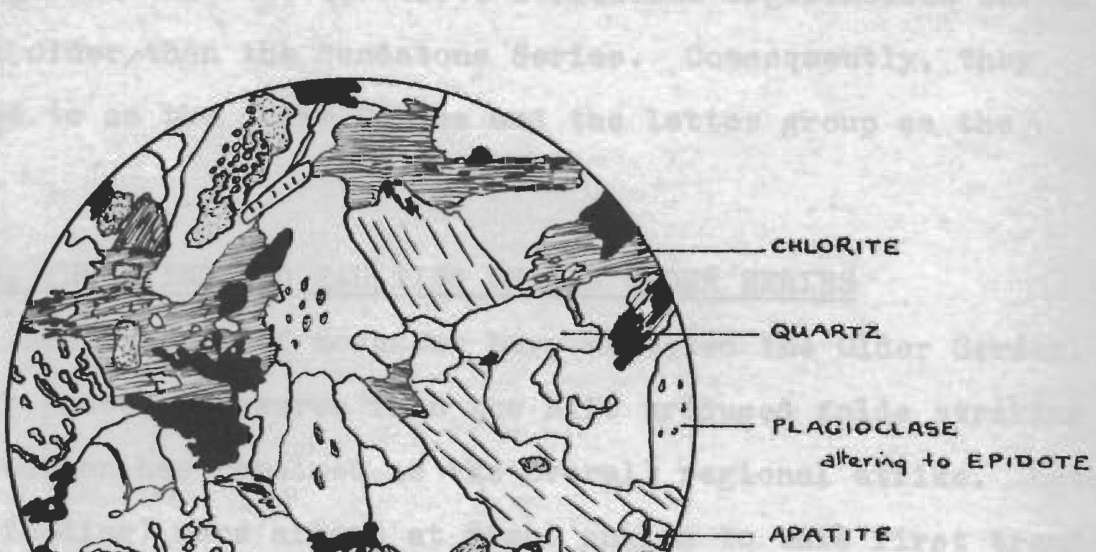
ROCK SLIDE 2 QUARTZITE of Sandstone Series

Locality :- South of Pampa Blanca.



ROCK SLIDE 3. SANDSTONE

Locality :- S.W. of Trapiche farm.



ROCK SLIDE 4 ALTERED DIORITE

Locality :- S.W. of Lago Cochahuma

GEOLOGICAL HISTORY & SEQUENCE OF EVENTS

6 (i) FOSSIL DATING

Only three fossils were discovered:

a) A small inarticulate brachiopod found in iron-stained poor slates at the S.W. edge of the circular lake immediately S. of Sina Pass.

b) A rhynchonellid found 1" from the base of the laminated tuff underlying the pillow lavas.

c) A cavity in sandstone 1 mile S.W. of Trapiche Stock Farm. The cavity was heavily crusted with iron-oxide and was thought to represent a leached brachiopod.

Dr. D.V. Ager reports that all three specimens are quite indeterminate.

It is suggested that the Quartzite Series and Argillaceous Series are a good deal older than the Sandstone Series. Consequently, they will be referred to as the Older Series and the latter group as the Younger Series.

6 (ii) FOLDING, THRUSTING AND FAULTING OF THE OLDER SERIES

At least three phases of movement have affected the Older Series. During the first phase, pressures from the N.E. produced folds striking 150°. This direction has remained as the overall regional strike. Later movements (2nd folding) were almost at right angles to this first trend and were produced by pressures in a 150°-330° direction.

The third movements, which resulted in deformation of the earlier, first-fold cleavage, came once again from the N.E. Possibly they belong to a late stage of the first folding, but it is at least probable that they were subsequent to the N.W.-S.E. pressures (2nd folding) and perhaps associated with the formation of the Palomani Lakes' Thrust (which strikes 003°) and the folding of the Younger Series (whose axial planes strike 173°). Faulting, which displaces the Palomani Lakes' Thrust, may be considered as a result of fold-pressure relaxation.

6 (iii) FOLDING, THRUSTING AND FAULTING OF THE YOUNGER SERIES

Dominant pressures acted in an E.-W. direction. The writer believes these to have come from the east, possibly the movements which produced the Palomani Lakes' Thrust. However, his colleague found a westerly-dipping thrust to the west of Rio Trapiche, which would suggest movement in the opposite direction. The E.-W. fault N. of L.Cololo, which cuts the Younger Series, is a normal, high-angle dip fault with downthrow to the south.

6 (iv) IGNEOUS INTRUSIVE ACTIVITY

A pear-shaped diorite boss lies to the S.W. of L.Cochahuma. Hand specimens of this purplish-coloured rock appear to be fairly fresh, but in thin section it is seen that the rock has been sufficiently metamorphosed to warrant the title of a low (chlorite)-grade edpidiorite. Basic plagioclase has been transformed to epidote plus a more albitic plagioclase, whilst the ferromagnesian minerals are largely made-over to chlorite and epidate.

The projected strike of the thrust west of Rio Trapiche intersects this intrusion. Thus the igneous rock was probably injected along this or a closely parallel plane of weakness at the time of thrust movement.

The dolerite dyke of Sina Valley presumably post-dates the first folding since it is intruded parallel to the first-fold cleavage.

6 (v) GLACIOLOGICAL AND GEOMORHOLOGICAL HISTORY

In N. Bolivia and S. Peru, several periods of profound erosion and peneplanation have been established by a number of workers (e.g. Newell). The most prominent surface thus produced, the "Puna" surface, dates from late Tertiary time, although in the Bolivian Altiplano a post-Puno (Miocene?) peneplanation merges with the later feature to produce the regional Puna surface.

The Puna surface is described as a "post-mature" erosional feature produced by sub-aaerial agencies. It truncates both of the opposed thrust sets which converge on the Titicaca Basin and is itself warped beneath this basin and there cut by several high-angle faults.

The present height of the Andean arch is thought to result from late Pliocene to Recent epeirogenesis. Many interesting theories speculate on this very recent upheaval and the former existence of a number of large and apparently prosperous civilisations in a region which is now inhospitable and unrewarding.

In the Nudo de Apolobamba, it is possible that the pampa represents a remnant of an erosion surface above which the mountains stood as monadnocks. Certainly the formation of a piedmont glacier implies a more subdued terrain at the foot of the mountain range. However, the only coarse clastic deposits found were those of the moraines themselves; which are presumably of Pleistocene to Recent age and therefore post-uplift. Thus considerable modification of the original topography has obscured any evidence of the pre-Pleistocene nature of the sub-pampa surface.

The pampa lake is here considered to be late-Pleistocene; and the Moraine Belt to result from Pleistocene to Recent accumulation.

The present drainage system of the mountains is probably little different from its pre-Pleistocene form. Similarly, it is likely that the sub-pampa surface was drained by S-flowing streams as at present.

It is not known when the pampa lake finally disappeared. Newell (op. cit.) indicates a contraction of his ancestral Lake Ballivian in early Pleistocene times to occupy the central area of the Titicaca Basin; and a further drop in level of L.Titicaca in post-early Pleistocene times. Both of these effects are considered to be too early to influence the pampa lake.

6 (vi) SEQUENCE OF EVENTS

12. Continuation of glacier retreat. Draining of pampa lake. Initiation of pampa drainage. Formation of present day topography.

11. Retreat of glaciers (Late Pleist?). Formation of pampa lake. Initiation of drainage of mountain areas.

10. Heavy glaciation (Pleistocene?). Blanketing of the topography by thick moraine and outwash deposits.

9. Fairly rapid epeirogenic uplift to altitudes affected by the Pleistocene glaciation. (Uplift prob. continued later to altitudes affected by normal mountain glaciation, i.e. above the normal snow line).

8. Erosion of the region to a fairly mature topography by marine and/or sub-aerial agencies. The mountains remained upstanding above the general erosion level.

7. Intrusion of the diorite boss along a plane of weakness (Thrust plane?). The diorite is quite strongly altered and is therefore likely to be partially contemporaneous with the 3rd Folding (6). The dolerite dyke could be of any age younger than the 1st folding (2).

6. 3rd. folding in an E.-W. direction affected the Sandstone Series, probably produced the Palomani Lakes' Thrust, probably crumpled the 1st Fold cleavage and produced more quartz sweat-out veins. These movements possibly produced the westerly dipping thrust W. of Rio Trapiche. Pressure relaxation resulted in several tension (normal) faults.

5. Submergence (?) and resumption of marine conditions. Shallow water sandstones deposited (L.White Sandstone) probably underlain by shaly rocks with thin sandstones. Very well rounded quartz grains from a desert environment are included in the L.White Sandstone. Purple shales, a purplish sandstone and more White Sandstone form younger members of this sedimentary sequence.

4. Stratigraphical break:
Uplift (?) and erosion (?) of Older Series.

3. Second folding of Older Series by pressures from N.W.-S.E. Folding less pronounced than 1st folding. No 2nd fold cleavage.

2. First folding of Older Series by pressures from N.E. Development of fracture - and slaty-cleavage and of quartz sweat-out veins.

1. Sedimentation of the Quartzite and Argillaceous Series under non-terrestrial conditions. Rare development of current-bedding in the quartzites may denote shallow water deposition. On the other hand a similarity has been noted between these Series and the Culm facies of N.Devon. The latter is thought to represent a geosynclinal deposit. It may be significant that small occurrences of a poor coal have been reported from near Pelechuco. The absence of coarse sediment is noteworthy.

7. PREVIOUS WORK

Reference: N.D. Newell "The Geology of the Lake Titicaca region, Peru and Bolivia". Geological Society of America Memoir 36. (1949).

7 (i) Newell's work was confined to the Peruvian site of the frontier in the Nudo de Apolobamba, although a traverse was made, in conjunction with Dr. Federico Ahlfeld, along the frontier from Cojata to Trapiche Stock Farm, thence to Poto. Newell's report includes observations by Ahlfeld on adjacent Bolivian areas.

The present work agrees with Newell in most respects, differing here and there only in points of detail. A major divergence of opinion concerns the rocks to the west of Rio Trapiche, which he has mapped as being partly Devonian and partly Cretaceous (Vilquechico Formation). We found no rocks of the Older Series along this ridge above the level of the pampa.

Moreover, our observations of the Sandstone Series do not coincide with his description of the Vilquechico Formation ("Dark olive-grey siliceous shale with several beds of white quartzite"), but rather with the descriptions of the Cotacucho Group ("Pink and red massive sandstone overlain and underlain by red gypsiferous shales; contains a persistent sandstone unit of probable eolian origin").

	(Munani Formation	800 metres
U. Cretaceous	(Vilquechico Formation	680 m.
	(Cotacucho Group	1100 m.

From Newell's map and sections, his Suches Thrust appears to emerge at a low angle along a line joining the centres of Lakes Cololo and Suches; and then to intersect the ridge to the W. of Rio Trapiche, thus bringing Devonian rocks to rest on Cretaceous. The Palomani Lakes' Thrust corresponds readily to the eastern outcrop of Newell's Suches Thrust. It is unlikely, however, to intersect the ridge to the W. of Finca Aurora. In addition, rocks of the Argillaceous Series are found beneath the thrust (although this last fact could find an explanation if the thrust were only just beginning to have movement and was still confined to Devonian beds).

A better suggestion invokes two thrusts as shown diagrammatically in Fig. 6.

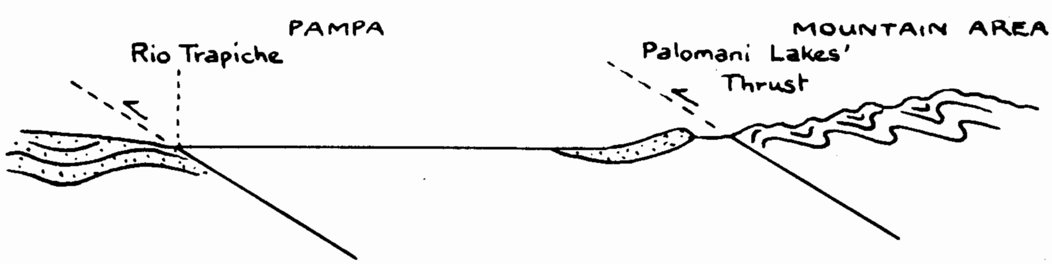


FIG. 6

8. CONCLUDING REMARKS

In the foregoing pages, the geology of the Nudo de Apolobamba has been treated from a structural aspect. This was perhaps the only way in which useful progress could be made. It should be emphasised, however, that the principal concern of the field work was production of a reconnaissance geological map only and so as a consequence the geologists covered as large an area as possible, thereby diluting that density of field readings which is so necessary for a structural analysis.

More work needs to be done in the area before the existence of a second folding (N.W.-S.E. pressures) is finally established. In addition, the junction between Older and Younger Series west of Rio Trapiche could bear re-examination; and finally it would be more profitable to measure the axial planes of cleavage "rucks" rather than their axes.

7 Survey Report

W.H. Melbourne

Introduction

The survey of the Nudo do Apolobamba received an excellent start from the work of the Peru-Bolivia Border Commission Survey conducted under the auspices of the Royal Geographical Society.

For this border survey an accurate base line was measured near Poto, the latitude and longitude determined, and a triangulation carried from Lago Titicaca northwards over the Paso de Sina and several hundred miles through the jungle to the Brazilian border.

During the triangulation over the pampa to the Paso de Sina about a dozen prominent points had been located by intersection in the main Apolobamba group. After some initial difficulties it was possible to relocate four of these intersected points and use them as the base for the detailed topographical survey carried out by this expedition. It was in fact possible to recognise all the intersected points, although only four and subsequently a fifth were points sufficiently well defined to use accurately, the other being rounded snow domes or flat topped peaks with a possibility of two or more intersection points. During the plane table survey these points were used and rechecked against each other many times, and always with no greater error than ± 5 metres in either azimuth or elevation. This error being the extreme limit of the accuracy of the plane table was accepted as satisfactory. Had it not been possible to use these intersected points then it would have been necessary to waste considerable time carrying a triangulation from two of the border survey cairns near West Suches and Trapiche.

The apparent good start given to the survey by the border survey also very nearly caused a disastrous mistake. During the border survey an attempt had been made (obviously from a long distance) to fill in a little of the detail on both sides of the main mountain group, and the Rio Sanches-Cuchu on the east side had been marked as being the main river draining the centre of the mountains. However it was later discovered that the Rio Sanches-Cuchu finishes just below Soral Este peak, and 80% of the high mountain group, including the two large glacier icefields drain westwards to the Rio Suches and not eastwards. The watershed in effect being the three mile wide glacier between Azucarani and Soral Oeste.

Surveying Equipment

The area to be surveyed covered approximately 150 square miles, all of which was mountainous and glaciated and nearly all over 14,000 ft. Because of this the choice of survey gear was limited to what could be carried on top of food and alpine type equipment. Apart from several prismatic compasses and barometric levels used by other members the following is a list of the instruments (loaned by the Royal Geographical Society) and used in the field.

1 Watts microptic theodolite
1 2¼" x 2¼" camera, fitting the theodolite
1 18" x 12" plane table (and alidade)
1 lightwieght tripod (fitting both the plane table and theodolite)
1 Abney clinometer
1 prismatic compass (oil filled)
1 barometric level
1 100 ft steel tape
1 slide rule and book of log and trig tables.

A trough compass would have been an extremely valuable addition and time saver when using the plane table. It is also worth mentioning here that if two or more surveyors are in the field then it is also essential to have a tripod for both the theodolite and the plane table. With the only tripod monopolised by the plane table a considerable number of opportunities to use the photo theodolite were unfortunately lost.

Except for the photo theodolite which will be dealt with separately, only two instruments were slightly unsatisfactory.

The alidade sights were far too short for use in a mountainous area, and the string sight across the top is quite useless if the wind is at all strong. It suggested that an alidade on a one foot base should have sights at least five inches high. The prismatic compasses were oil filled, and the presence of air bubbles were a source of constant annoyance and inaccuracy.

The camera used on the theodolite for the photo theodolite work was in an experimental stage and as such had many faults. The camera was a 2¼" x 2¼" Zeiss Ikon Nettar with a 75 cm. focal length lens, fixed in the open position to a base plate. The purely mechanical faults were easily overcome although nothing could be done about such faults as the lens system being not sufficiently ridgidly attached to the camera base. The difficulty came about during the calibration; which unfortunately had to be carried out in the field in windy and dusty conditions. Four V grooves had been cut in the frame at the back of the camera next to the film, and a piece of ground perspex had been supplied with two inked cross lines for the purpose of calibration. The cross lines were too thick and did not match the grooves in the frame and it was impossible to hold the perspex in place and traverse the theodolite at the same time; hence using the cross lines was useless and in any case this method of calibration is inaccurate in principal. The more correct method of calibration using the grooves in the frame became equally inaccurate due to the light intensity being insufficient near the edges to see the grooves. A calibration of sorts was eventually carried out, but which will have to be corrected from photographs which have been taken of known points. The simplest way of overcoming the calibration problem is to fix short pointers to the frame in place of the grooves. It would then be possible to see these with a light ground glass plate (not perspex) and the pointers would also appear on the negative in the same way as the grooves.

Surveying Techniques

The weather reports available on the area (and the Andes in general) caused some concern in London as to the techniques which could be used. It was initially thought that most of the survey would have to be carried out using the photo theodolite, taking stereo pairs wherever possible; and that the plane table would only be of use at low altitudes. This fortunately proved to be incorrect and it was possible to carry out a plane table survey of the entire area; the highest station being established on the summit of Matchu Suchi Coochi at 5679 metres (18,633 ft). It is granted to previous forcasters of frost-bite and polar cold that at times it was extremely uncomfortable to operate the plane table, but rarely impossible. There had been several warnings of cloud blotting out the area by midday on most days, and this was found out to be only too true in any of the valleys running north or east to the Amazon jungle low-lands and the Rio Beni. This was inconvenient, but being more or less regular it was possible when in these areas to time schedules so as to survey early in the morning and to shift camp or do computations in the afternoon.

The photo theodolite was used to photograph the snouts of glaciers for glaciological purposes. On five of the highest survey stations the photo theodolite was used to take a circular sweep of 12 photographs at 30° intervals for future reference rather than to be used on the map which was completed on the plane table. On two occasions it was possible to mount the theodolite on a cairn without the tripod, but all the other high stations were on ice, necessitating the use of a tripod. A pack frame was useful on several occasions in soft snow to use as a base for the tripod.

No time was spent developing a technique of taking stereo pairs as this became unecessary for the mapping. However it was noted that mapping using the stereo pair method is very difficult in such a mountainous area. The greatest difficulty being in establishing base lines and in particular one with a possibility of seeing a useful area from either end. Because of this the stereo pair method is not at all attractive on the type of survey undertaken on this expedition, and also the weeks or months of plotting work required on return does little to recommend it. The stereo pair method also has the disadvantage of not producing the map in the field, which is a valuable consideration in a completely unmapped and unexplored area.

The plane table survey was carried out on a scale of 1:50,000. The most important factor in the plane table surveying technique was to establish stations as high as possible. From high survey stations it was easier to get an accurate fix and the field of view was much greater, hence reducing the number of stations required. Over forty plane table stations were established and three over 5450 m. (18,000 ft). On establishing a station site the plane table was set up and leveled using the climoneter base, then approximately oriented with the prismatic compass and finally oriented using a three point fix. It was usually possible to check the three point fix with at least two other known points. The altitude of the station was then determined from at least two of the known points with the climoneter (and occasionally the theodolite) and using the base distance measured from the plane table sheet.

The 150 metre interval contouring was obtained by intersecting and obtaining spot heights of prominent land marks, and the contouring done on the map by interpolation: using this method it was possible to keep the contouring accuracy to within ± 20 metres in the horizontal plane (although the stations were located within ± 5 metres) and heights quoted on the map are within ± 10 metres.

General

The first reliable plane table fix was established near the main glacier east of Matchu Suchi Coochi. This was after the first series of ascents of the Matchu Suchi Coochi group during which four good intersection points of the Peru-Bolivia border survey were definately relocated. Previous to this it had been almost impossible to relocate these old survey points with any certainty. The details of the four points (and later the fifth) used from the border survey are as follows:

Matchu Suchi Coochi	Lat. 14°45'48", Long 69°11'39" Height 5679m (18633 ft)
Rock Spike S.E. of Palomani Tranca	Lat 14° 43'31" Long 69° 14'19" Height 5626 m (18460 ft)
Soral Oeste	Lat. 14° 42'41" Long 69° 10'42" Height 5641 m (18508 ft)
Soral Este	Lat. 14° 43'29" Long 69° 9'14" Height 5471 m (17949 ft)
Palomani Grande	Lat. 14° 42'54" Long 69°14'52" Height 5769 m (18926 ft)

Of these points all except the Rock Spike were ice peaks, and although these were sharp points the actual ice summit could have moved two or three metres since the original border survey.

From the first station the survey was carried all around the large southern glacier between Azucarani and Matchu Suchi Coochi. From here the survey continued over the glacier down the Sanches-cuchu valley to Pelechuco and northwards behind the Soral Este peak. On returning to the western side again a base was established at the San Antonio hut and from there the northern glaciers and peaks around Chupi Orco and behind Soral Oeste were surveyed, and also the lower valleys were surveyed down to Lago Suches. The last survey trip was made over a pass and down the valley west of Matchu Suchi Coochi, round the Pelechuco Huaracha and down the Pelechuco Pass towards Katantica.

8 Glaciological Observations G.C. Bratt

It was known from the R.G.S. border survey report (1) and from Bowman (2) that large glaciers existed in the border range but neither the location nor any details concerning them existed. It was planned that the glaciers of the Apolobamba region should be accurately mapped and as many as possible visited so that their state of advance or recession and their general characteristics noted.

The glacier positions are shown in the accompanying map (see pocket) which is a tracing from a plane table survey conducted by Melbourne.

Because of other work and the distances involved only a few glaciers could be visited more than once so that rates of movement are only known for a few glaciers. The results obtained are given in Table I. (For glacier location see map in pocket)

TABLE I

Rates of Glacial Front Movement

Glacier	Rate	Ins/day	Period of measurement days
P_1	2	Advance	36
P_2	1	"	
M_2	$1\frac{1}{4}$	"	9
M_3	$1\frac{1}{2}$	"	
C_9	$1\frac{1}{8}$	"	2
T_3 north front	$1\frac{1}{2}$	"	21
central "	static		
south "	2	retreat	

The rates are small but are significant as the fronts of many glaciers are reaching past old terminal moraines and covering plants which are at least 10 years old. Thus the advances must be something more than a seasonal fluctuation. The fact that all the glaciers are not acting concertedly (see table II) is due no doubt, to the non existance of a central snow field supplying the glaciers.

A very noticeable feature of the glaciers in this region is the difference in the altitudes of the snouts of the north and south facing glaciers (see table II) The south facing glaciers from any given ridgereach 1 - 2000 ft lower down the mountain side than those on the northern slopes e.g. Matchu Suchi Coochi ridge. The type of glacier is also distinctly different - the southern glaciers descend steeply over a broad area which the northern glaciers are almost always small corrie glaciers. There are several apparently anomalous glaciers but each of these has some peculiar feature as shown below:- (p. 44)

TABLE II

Glacier No,	Flow Axis °Mag.	Alt of Snout ft.	Motion of Snout	Approx. Ht. of supplying snowfield	Approx length ft.	Av. Grad. in Degrees
Pelechuco Pass						
P_1	200	15,500	Advancing	18,000	7,800	18
P_2	205	15,600	"	18,000	6.700	20
P_3	180	15,350	Retreating	18,000	5,700	25
P_4	220	14,900	Advancing	18,300	7,300	25
Matchu Suchi Coochi						
M_1	360	17,650	Retreating	18,000	1,000	19
M_2	360	17,100	Advancing	"	3,000	17
M_3	360	16,900	"	"	5,700	21
M_4	30	17,300	-	"	2,000	19
M_5	360	17,800	-	"	600	19
South Wall of Pelechuco Pass						
O_1	220	16,000	-	17,200	1,000	45

TABLE II (Contd.)

Glacier No.	Flow Axis °Mag.	Alt of Snout ft.	Motion of Snout	Approx. Ht. of supply snowfield	Approx length ft.	Av.Grad. in Degree
Soral Este						
S_1	130	15,000	Advancing	18,500	3,200	48
S_2	300	15,000	"	17,500	5,700	24
S_3	180	15,650	-	18,000	3,600	33
S_4	180	15,650	-	18,000	3,200	33
S_5	180	15,200	?	17,500	3,200	35
N_1	90	15,650	Static	16,500	1,000	40
N_2	Glacial Corrie but no glacier					
N_3	50	16,700	-	18,000	1,500	41
N_4	30	16,250	Advancing	17,700	2,000	35
Nether Soral Este						
B_1	-	15,100	Advancing	16,000	2,400	20
B_2	-	15,400	-	"	300	64
Glaciers between Suches Valley and Pelechuco Pass						
W_1	240	16,650	Retreating	18,000	3,600	21
W_2	220	16,400	"	18,500	4,200	26
W_3 (a)	270	16,700	"	18,500	4,100	24
(b)	270	16,600	"	18,500	4,100	24
W_4	300	16,350	Advancing	18,500	3,600	31
Puina Valley						
L_1	55	15,150	Retreating	18,500	4,000	39
L_2	55	15,500	"	17,600	2,000	45
Palomani Basin						
C_1	130	16,700	-	18,500	3,600	26
C_2	90	17,000	-	18,500	1,500	45
C_3	90	17,100	-	[illegible]	5,200	20
C_4 (a)	40	17,700	-	[illegible]	3,000	23
(b)	50	17,600	-	19,000	4,000	19
C_5	90	17,100	-	19,000	5,000	21

TABLE II (Contd)

Glacier No.	Flow Axis °Mag.	Alt. of Snout ft.	Motion of Snout	Approx. Ht. of supply snowfield	Aprox length ft.	Av. Grad. in Degree
Palomani Basin (Contd)						
C_6	160	16,400	Retreating	19,700	16,000	8
C_7	180	16,850	-	18,500	8,000	13
C_8	220	16,600	-	17,800	10,000	7
C_9	260	16,500	Advancing	18,500	15,600	7
C_{10} (a)	270	16,900	"	17,900	5, 000	11
(b)	270	16,800	Retreating	17,900	5,000	11
West Soral						
T_1	-	16,500	-	18,500	-	
T_2	--	15,800	-	"	-	
T_3	305	15,900	Advancing & Retreating	"	12,000	12
Chupi Orco						
R_1	-	17,100	-	-	-	-
R_2	-	16,900	-	-	-	-
R_3	120	14,750	-	19,700	20,000	15
Katantika						
K_1	10	16,100	-	17,000	-	-
K_2	20	15,800	-	17,000	-	-
K_3	10	16,100	-	18,000	2,800	34
Azucarani						
A_1	10	15,600	Retreating	18,000	3,000	39

Cont. from P42

Glacier N1 - This descends to a very low level but flows due east and appears to result from a ridge which first catches the vapour laden air rising from the jungles around Quexra

Glacier L_1 - Although at the snout the ice is flowing N.E. this glacier is fed from south facing snow slopes of the western Soral peaks.

The snow cover on south facing slopes was always considerably deeper and less consolidated than on the northern slopes. Melting on north and south facing snows is also quite different in character. On the southern slopes the melting was so slight so as to produce no change in appearance (except on some days there was a thin coating of ice flakes which blew about in the wind). On northern slopes there were two different types of formation arising from the action of the sun. The first type consisted of a series of parallel grooves about 1" across and facing the approximate noon position of the sun. The second type of formation consisted of sets of pinnacles with the lower side about 1 ft. high and the upper side about 3" high. A face covered with these pinnacles appeared to have a set of terraces on it and gave much help when moving on these slopes.

The cause of the great differnces between north and south facing snow slopes may be understood if one considers the extreme sun positions (mid-summer, mid-winter)and the weather conditions prevailing at these times. If a typical ridge e.g. the Soral Este ridge is considered (see fig.1 for an approximate representation) the view factors for radiant heating will be.

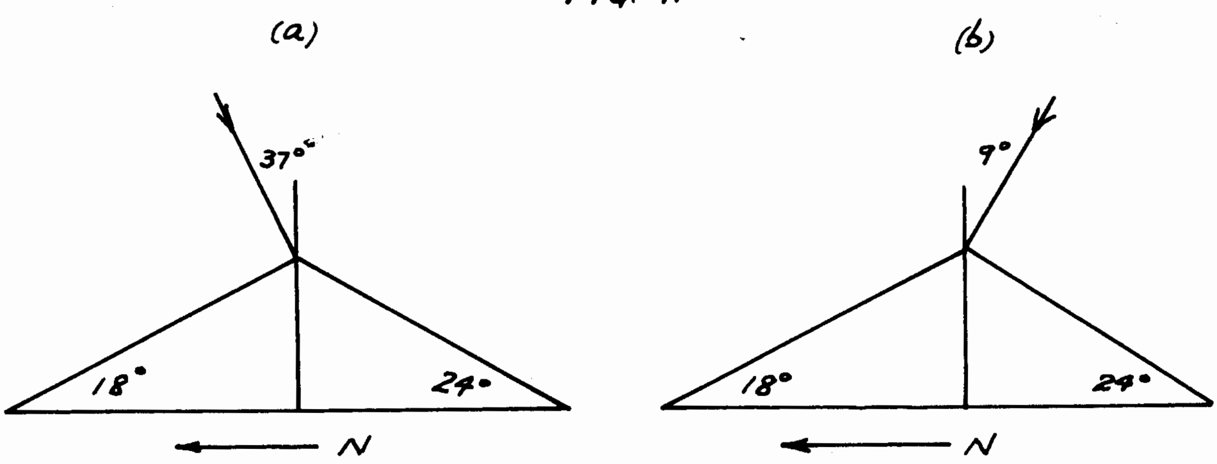
	Mid-Winter	Mid-summer
Southern Slopes	0.49	0.97
Northern Slopes	0.95	0.96

These values indicate that in winter the melting on the northern slopes should be almost twice as great as, and in summer equal to, the melting on the southern slopes (provided radiation is the principal method of heat transfer). Usually during winter the sky is clear but the summer is cloudy and most of the snow falls occur then so that ablation would be expected to be controlled by winter conditions with the markedly greater melting on the northern slopes.

That melting is largely controlled by radiation is illustrated by the fact that on a day when the air temperature remained near zero all day a new bright tin lid melted down between 1" and 4" (it slanted) in 6 hrs.

The effect of this preferential heating is particularly well illustrated on the ridge forming the southern boundary of the Pelechuco Pass and also on the ridge directly north of Soral Este. On the northern side of both these ridges there is no glaciation but on the southern sides glaciers descend to 16,000 and 15,200 ft. respectively.

FIG. 1.



An approximate representation of the sun acting on the East Soral ridge
(a) Mid-Winter (June) (b) Mid-Summer (December)

Some detailed notes on conditions at the various glacier snouts visited will now be given.

Pelechuco Pass Glacier P_1 - The snout of this glacier has advanced so far that it is pushing into an ice cored moraine left by a previous retreat. On the western edge the moraine is covering up well established grass patches. The ice which is pushing forward is fairly thin and is actually thicker at the snout than 20ft. back. This suggests that the advance may be near to its maximum and will soon be followed by retreat.

Glacier P_2 - The snout of this glacier is very steep ($60-70^{\circ}$) and quite free from debris. Between the snout and the nearest moraine(dry) there is a distance of 40 yds. completely free from plant growth. The front is in most places moving forward and pushing up heaps of boulders.

Glacier P_3 - This glacier has wide (>100 yds) ice covered moraines along its edges and also 100 yds in front of the clean ice front. The clean ice front is overhanging ($> 20^{\circ}$) and appears to fall off as leaves of ice 1-6ft thick into a small lake. The outlet stream of the lake has cut down about 15 ft through an old terminal moraine and has exposed an excellent varve system.

Glacier P_4 - The snout of this glacier is an icefall and judging by the amount of debris it is fairly active . The ice near the snout is less than 50 ft thick. It can seem to be advancing since there are pushed up moraines on its Western edge and lichen and moss covered rocks are being shifted.

Matchu Saochi Coochi Glaciers

Glacier M_3 - This glacier was pushing moraine over a moss and grass patch which could not have been less than 10 years old (estimated from the growth in prospecting pits of known age). A measurement of the rate of movement of the base of the glacier was made and this was found to agree with the rate of advance of the front (5" in 9 days) suggesting that the glacier is sliding as a block down the valley. The movement of the glacier base was obtained by measuring the displacement of an icicle suspended from the roof of an ice cavern. The front of this glacier was quite vertical. The lower parts of the glacier consisted of separate or almost separate blocks.

Glacier M_2 - The snout of this glacier appears to be an almost separate block (as was glacier 3) but with the difference that the block is in a much more advanced state of melting. The front is advancing in most places but in a few places the lobes have become thin and are rotting back from their most advanced position. There are well established clumps of plants only 10 yds from the clean ice front. There is a great deal of plant debris in the moraines and the main drainage stream has algae in it ~~even~~ underneath the ice.

Glacier M_1 - This glacier has recently passed through an advance stage pushing up an 18" moraine but has now retreated up to 2 ft behind this.

Eastern Soral Glaciers S_2 - The glacier appears to have thickened on the western edge and is scouring the side of an old high moraine. The snout is steep (45^o) and pushing on a dry moraine.

Glaciers between Suches Valley and Pelechuco Pass

The first three of these glaciers show many similar features. All have steep snouts and western edges and appear to have just passed through an advancing stage but are now retreating. The fourth has an ice-fall front of thin ice ($<$50ft) showing considerable activity. On the western edge the ice comes below the cliff and has caught up with an older ice covered moraine.

Puina Valley Glacier L_1 - Although at the snout this glacier is flowing northwards it is fed via a very steep ice-fall from the south facing snows of the western Sorals. The snout is quite smooth and shows no effects of the ice fall. On the eastern edge a small lobe appears to be advancing but elsewhere there are large ice cored moraines in front of the snout with the drainage streams between.

Palomani Basin Glaciers

Glacier C_6 - The front of this glacier consists of vertical cliffs but they are rotten and collapsing everywhere. On both edges there are large ice cored moraines. On the western edge there is an isolated ice lobe tip 10 yds from the ice edge and very near the closest moraine. On the eastern edge there is an isolated ice pinnacle (10 ft high) which is 20 yds in front of the ice and 10 yds in front of small dry moraine. It seems that fairly recently the glacier has advanced markedly then retreated leaving the stranded pinnacle. Since then there has been another smaller advance. This glacier and also glacier C_5 have the peculiar feature that within a mile of the snout and without any apparent change in bed slope a system of transverse crevasses develop and the glacier rapidly become a series of knife edge ridges.

Glacier C_9- This glacier appeared to be advancing very rapidly all along its front. Large boulders and gravel were being pushed along and in one place had pushed up into a ridge 15 ft high and 20 ft broad. There was a continuous roll of material down the forward slope of these moraines on to old grass clumps in front.

Glacier C_{10}(a) - This glacier is pushing up big moraines on its northern edge and the discharge stream is thick with rock debris. On the southern edge a previous advance (recent) has stranded ice 100 ft in front of the present snout.

Glacier C_{10}(b) - This glacier has pushed a hugh lobe of ice almost at right angles to its front so that it passes about 100 yds in front of glacier 10(a). The lobe is now in a state of decay.

West Soral Glacier T_3 - This glacier has three main sources (a) end rock peak of West Sorals (b) the main ice ridge of the west Sorals and (c) the snow basin between Azucarani and the Matchu Scochi Coochi peaks. It is probably that the northern side of the front is supplied from (a), the southern side of the front from (b) and that the ice from (c) never reaches the true front but ends in a false front about 1½ miles further east. As noted before the N edge is advancing while the southern edge is retreating fairly rapidly.

Azucarani Glacier A_1 - The snout of this glacier although flowing north is fed from the snow basin on the south of Azucarani. There is an ice-fall 100 yds from the snout but there is no undulations at the snout. There are hugh ice covered moraines extending 60 yds from the ice front.

Glacial Moraines

All the glaciers visited showed very high lateral moraines which contained unweathered debris and very little plant cover. Most of these moraines were of the order of 500 ft above the present level of the glacier. Mostly they consisted of fairly uniformly fine ground rock but those near the Azucarani glacier were a chaos of large and small rocks and mud. In many valleys the floor consists of fairly uniformly sized pebbles and the advancing glaciers push very regular moraines. In one place where there was a succession of small terminal moraines it was estimated that the glacier pushed up 3" of moraine for every yard of advance. Further investigation on this aspect would be useful since it could give information on the position of the ice front immediately preceding any particular advance.

Cornices - Although high winds were experienced during the trip and locals state that the winds increase even further in September practically no true wind cornices were observed. However a type of cornice forms due to the action of the sun. On ridges which are heavily glaciated on the southern side but not, or only slightly, on the northern side a passage or trench often 20 yds across develops between the rock and the snow crest.

References - (1) Peru-Bolivia Boundary Commission 1911 - 1913

(2) Andes of Southern Peru. I.Bowman American Geog.Soc. 1916

9 Meteorological Observations

G.C. Bratt

Although they would have been valuable no comprehensive series of meteorological measurements was planned. It was intended merely to measure maximum and minimum temperatures and make general observations of wind direction, snowfall etc.

For temperature measurements two max. and min. thermometers were borrowed from the R.G.S. These thermometers were of a very old style with separate bulbs and stems for measurement of each extreme. When unpacked in Bolivia the columns of both mercury and alcohol were broken and great difficulty was experienced in re-uniting them. In fact only the minimum thermometers could be made to operate satisfactorily.

The readings taken from one minimum thermometer together with the altitude of measurement and general weather conditions are tabulated below. The positions of the camps is shown on map in Section 10. The heights given are barometric heights (Tommen's) with corrections from survey results. The winds have been classified as very weak (VW) through to very strong (VS), as no reliable indicators were available for gauging Beaufort numbers.

Date.	Camp.	Altitude Ft.	Min. Temp. °F.	Wind.	Snow.	Cloud.
July						
17	-	-	-	West(s)	1" 12-4pm.	
18	2	16,450	18	East(w)	-	Obscuring E. Sorals.
19	3	15,650	28	West(w)	-	Overcast all day.
20	3	"	23	" (s)	-	-
21	3	"	18	- (s)	-	-
22	4	17,000	26	East(w)	-	Clear morning E.Sorals obscured by 2pm
23	4	"	22	" "	-	"
24	4	"	20	West "	-	Clear all day.
25	4	"	28	" "	-	"
26	4	"	16.5	" "	-	"
27	4	"	24	" "	-	"
28	4	"	15	" "	-	"
29	4	"	18	" (s)	-	Overcast.
30	4	"	16	" (vs)	-	Clear.
31	4	"	18	" (s)	-	"
Aug.						
1	5	16,850	23	East(w)	2" 11-6pm.	Visibility 100 yds.at 14,700 ft.
2	5	"	22	East(w-vs)	2"all day.	Limited visibility.
3	5	"	18	West(w-vs)	½"1-5pm.	Cloudy morning but clear evening after snow.
4	5	"	17.5	West(w)	Slight 1-3	Clear morning & evening. Hail & thunder 1-3.
5	6	14,900	29	West(w-s)	2"3-5pm.	Clear morning & evening.
6	7	15,850	24	East(w)	-	Clear all day.
7	7	"	23	East(w)	-	Peaks in mist from 3pm.
8	7	"	23	-	-	"
9	6	14,900	21.5	East until 2pm. then West. (w)	1" 4-7pm.	Low cloud all day.
10	8	15,250	27	West(vs)	½" Overnight.	Clearing as day proceeded
11	3	15,650	28	" (w)	-	Cloudy.

Date.	Camp.	Altitude Ft.	Min. Temp. °F.	Wind.	Snow.	Cloud.
Aug. 12	9	15,750	24	East (w)	-	Peaks in cloud by 1pm.
13	9	"	22	West(w-s)	-	Clear all day.
14	9	"	17	West (w)	-	" " " Electrical storm beyond Sorals.
15	9	"	18	Slight gusts only.	-	Clear all day.
16	9	"	17	West(w-s)	-	" " "
17	10	17,700	-2*	N-NE(vs)	-	" " "
18	10	"		West(w)	-	" " "
19	9			East(vw)	-	Cloud on peaks from 3.becoming lower at night.
20	2	15,550		East(vw)	Light from 3pm.	Cloud coming from valley at 10.Snow at 3.
21	2	15,550		West(w)	Light snow from 3.30pm.	Clear in morning.
22	9	15,750		West(w)	1" from 12.30pm.	Clear in morning.
23	9	15,750	18.5	" (w-s)	½" from 12.30pm.	Clear in morning.

* This may not represent the true minimum temperature as the indicator cannot move any lower. In an effort to move the indicator from this position the alcohol thread was broken and could not be re-united.

A number of points can be noticed from the tabulated data : -

1) The minimum temperature seems to be little affected by the altitude (except for August 17th) but appears to have a cyclic rise and fall with a period of 3-4 days.

2) In the earlier part of the records the bad weather appears to be associated with easterly winds but in the latter parts is definitely associated with westerly winds.

3) Only on one occassion (Aug.2nd) did snow begin falling before noon.

Other information of interest is summarised below:-

1) Barometric changes never exceeded 200 ft (at 15,000 ft-18,000 ft) during any one day.

2) Maximum noon shade temperatures never exceeded 65°F.

3) The temperature drops rapidly between 6p.m. and dark (7.15p.m.) e.g. on 20th July the temperature dropped from 40° to 27°F in this period and then only dropped a further 4° by mid-night.

4) From local information it appears that the weather experienced was exceptional in two respects - the snow falls were unexpected and strong cold continuous winds were expected by mid-August but did not eventuate.

It is interesting to compare these observations with those made by other expeditions in the same and nearby areas.

1) The German expedition under H. Richter which visited the Apolobamba at about the same time as this expedition in 1957 reported temperatures as low as -22°F.

2) The Italian expedition under R.Merendi which visited the Apolobamba in 1958 claimed that the best climbing season was from mid-May to mid-August, that the minimum temperatures reached -22°F and the maximum day temperatures reached 77°F.

3) Hans Ertl who visited the Cordillera Real in 1952-53 makes the following comment(1) - "April, May and June are deemed the best season for mountaineering in the Cordillera Real. Polar cold condemns the winter months of July and August in South America while in September and October the feared nevados (snow-storms) often rage unexpectedly". The only temperature he quotes is -15°F on July 16th at 18,870 ft.

4) Piero Ghiglione(2) who visited the southern Peruvian Andes (Ausangate, Cayangate) in 1952 express the opinion that April till July and sometimes August are the best months for climbing. He also says that 1952 was a bad year and gives the lowest minimum temperature as -11°F on the 14th August at 19,850 ft.

It seems from these notes that Ertl has rather exaggerated conditions and that considering the altitude the weather is reasonably mild even until September.

Reference (1) H. Ertl. Mountain World 1953

(2) P. Ghighlione " " "

10 Mountaineering Report

J.W. Jenkinson

Two main factors affected the expeditions climbing activities in the Apolobamba region - the continuously fine weather and the deep soft snow on south facing slopes.

Details of the weather experienced are set out in section 9, but some general comments are given below:-

Of the 42 days spent in the area there were only 10 on which snow fell but on no occasion was a climb affected by these conditions. These snow falls were considered unseasonable by Sr. Farwig (president of the C.A.B.), the only adverse weather he expected was continuous strong cold winds in August. Although in mid-August several days of high winds were experienced, the predicted continuous winds did not appear to have been established before our departure.

During daylight hours no extra clothing (above sweater and windproof) were needed; nor were cold feet experienced, except when standing still for long periods in the snow, although feet were often wet all day. On one day of cold winds duvet jackets and overtrousers were found necessary when surveying on an exposed ridge at 18,300 ft.

The snow surfaces on north and south facing slopes were entirely different - on the north firm and at times icy while on the south soft and powdery (see sections 8). The north facing slopes were not always smooth but often melted to give a series of small terraces, greatly assisting movement. Travelling on south facing slopes invariably involved flogging a track through deep (up to thigh deep in places) powder snow. Sometimes a thin crust made progress even more exasperating. After a few encounters with these conditions south facing slopes were avoided whenever possible. Snow conditions did improve slightly between falls, but fresh snow led to renewed trouble even on north facing slopes.

The climbing activities can be conveniently divided into three phases directed at Matchu Suchi Coochi from Camp 4, the Soral Este ridge from Camp 7 and Soral Oeste from Camp 10. A detailed account of all the ascents is not given; instead a brief chronological list has been drawn up, supplemented with a full personal description of the two most representative climbs.

Climbing Itinery

July 21st Camp 4 established (for location of this and other camps see map P65)

July 22nd Bratt and Smith traversed four peaks on the Matchu Suchi Coochi ridge NW to SE and descended down glacier from a col NE of Matchu Suchi Coochi. Peak heights 5640, 5660, 5670, 5680 m.

Conditions: weather cloudless; long stretches of deep powder snow on the ridges made progress slow, in exposed and north facing snows the surface was hard enough to use crampons.

Jenkinson and Melbourne climbed a peak NE of Matchu Suchi Coochi by way of a glacier and a steep ice face; descended the North rock ridge. Peak height 5640m.

Conditions: weather cloudless; frozen snow on 70° slope required much step cutting

July 23rd Bratt and Smith attempted Soral Oeste via the West Soral glacier but abandoned it after taking 4½ hrs. to travel 2 miles and arriving within 1 mile of the ridge.

Conditions: deep powder snow and highly crevassed glacier edge made progress extremely slow.

Jenkinson, Melbourne and Caraffa climbed Pelechuco Huaracha via snow col., glacier, snow couloir, and corniced

ridge; descent by the same route. Peak height 5650 m.
Conditions: Cloudless day; snow deep and powdery requiring ~~waist~~ Knee deep track flogging, snow gully in good condition, finish up hard snow.

July 24th Bratt, Jenkinson, Melbourne, Smith ascended Azucarni via glacier and NW ridge; descent by the same route. Peak height 5580 m.
Conditions: cloudless day; patches of soft snow on flat glacier caused some trouble as did south facing ridge slopes; frozen snow on ridge gave good progress involving 2 steep ice pitches.

July 27th Bratt, Jenkinson and Caraffa traversed two more peaks on the Matchu Suchi Coochi ridge. These were SE of the peak climbed on July 22nd. Peak heights 5610, 5600 m.
Conditions: clear weather, hard snow with a little powder snow on the ridges.

July 28th Jenkinson and Melbourne climbed Matchu Suchi Coochi via the descent route of July 22nd to establish a survey station.

July 31st Bratt and Jenkinson climbed extreme NW peak of Matchu Suchi Coochi ridge via the NE ridge; descended by the same route. Peak height 5600 m.
Conditions: cloudless; snow hard, finish on alternating good and loose rock. Snow dome summit. Camp 5 established (16,900 ft)

August 1st - 2nd Bratt and Jenkinson made a reconnaissance of the Sanches-~~Coochoi~~ Cuchu valley and the valley north ~~side~~ of Soral Este. Because of deteriorating weather little was seen

August 3rd Melbourne and Smith attempted Soral Oeste by the edge of the West Soral glacier. Attempt abandoned when ¾ mile from ridge.

Conditions: weather clear early but deteriorating towards midday, deep powdery snow made progress slow.

Aug 5th Camp 7 established and Soral Este climbing routes reconnoitered.

Aug 6th Bratt, Jenkinson, Melbourne and Smith climbed peak SE of Soral Este by east corner thus avoiding gendarmes on NE ridge. Ridge to Soral Este was not possible in the time available. Melbourne and Smith descended by the N glacier and Bratt and Jenkinson traversed the peak to the SE and descended by E side of NE ridge. Peak heights 5380 and 5280 m.
Conditions: clear sky; rock initially icy and generally loose, snow very firm on ridge but tending to ball up on crampons in places.

Aug 7th Bratt, Jenkinson, Melbourne and Smith ascended Soral Este by the NE ridge. Melbourne and Smith descended the N glacier while Bratt and Jenkinson traversed two more peaks to the NW and descended directly from the last peak by a gully to the east. Peak heights 5470, 5430 and 5390 m.
Conditions: Weather initially fine, but deteriorated to give ground level cloud and snow. Snow conditions same as previous day.

Aug 12th Camp 10 established

Aug 15th Ewart, Garrard and Melbourne climbed Soral Oeste via the glacier and west ridge descending by the same route. Peak height 5640 m.
Conditions: weather cloudless; soft snow with a thin crust made progress slow but the ridge was slightly better.

Aug 16th Ewart, Garrard and Smith climbed the end snow dome west of the Oeste Soral ridge. Peak height 5560 m.

Conditions: clear day; deep soft snow except near the summit.

Bratt and Jenkinson climbed Chucayo Grande to establish a survey station.

Aug19th - 20th Ewart and Smith attempted to climb Katantika via the West Soral glacier and the ridges beyond. The attempt was abandoned because of a stolen food dump and poor visibility.

Conditions: low cloud and light snow; deep powder snow on the glacier.

- - - - - - - - -

Ascent of Pelechuco Huaracha 18,535 ft.

Melbourne, Caraffa and myself left Camp 4 at 7a.m. and walked up the valley to its head, passing by the badly crevassed section of the left hand glacier. Roping up, with Caraffa as the middleman, we climbed onto the glacier at a point where it swept underneath a hanging ice fall. Here a scoop in the ice led up past shattered ice blocks which indicated the danger of passing this way later in the day. Using the good frozen surface, which took us steeply up to the Col between Matchu Suchi Coochi and its NE neighbour, we made good progress and soon had a fine view of our objective across the intervening glacier. The best route appeared to be across the SE flowing glacier and on to the ridge some half a mile before the peak then traversing along over a minor peak to Pelechuco Huaracha. After an hour of exhausting work ploughing our way through knee deep snow we reached rock at the base of the ridge. Climbing over alternating snow and loose rock on easy slopes we gained the ridge. However, we were not to gain our summit directly from ~~the ridge~~ here.

The going was easy until within a quarter of a mile of the summit when our progress was barred by a sudden drop in the ridge. An overhanging buttress of loose rock dropped some hundred feet, no abseil belays could be found, and we were forced to descend to the glacier. This discontinuity which had not been visible from previously climbed peaks or the glacier below, caused us to lose eight hundred feet of height.

Following along the edge of the glacier we reached a scree on the eastern side of the mountain. From the top of this partly snow covered, frozen scree, a snow gully led up to the highest visible point on the ridge, which appeared to be the top. Kicking steps in the soft surface we regained the ridge in a rather exhausted condition but considerably higher than we had left it some two hours before. Some fifty yards further on we could see a pile of snow covered rock slabs which we again took for the top. However, on reaching this spot the true summit stood a further thirty feet above us, standing out at the end of some seventy yards of curving, corniced ridge, in a pyramid of ice.

I led on a traverse about twenty feet below the cornice while Melbourne on the rope end made a photographic record of the climb. Reaching the base of final pyramid, we found it consisted of an arch of frozen-snow over a partly filled crevasse. Icicles hung over the entrance and framed in the archway, Huanacuni, Cololo and the altiplano could be seen shimmering in the hot sun. In the distance Illiampu, the nearest point of the Cordillera Real, fifty miles away, was seen as a great yellow snow dome.

Twenty feet of steps were cut up the ice and at 1p.m. we sat astride the summit.

<u>The Soral Este Ridge</u>

On the 6th August an attempt on the Soral Este from its south east neighbour was dropped when it was seen that the long ridge was heavily corniced, crevassed and covered in soft snow. On the previous day Bratt and Jenkinson had examined a gully leading up to the north east ridge of Soral Este which avoided the three gendarmes on the lower section of the ridge. Since the snow ridge looked out of the question the gully and the north east ridge were attempted.

At 7.20 a.m. on August 7th, Bratt, Melbourne, Smith and myself left our tents at camp 7 and by 8.00 were roping up at the foot of the gully, Melbourne with Smith and Bratt with myself. At the beginning of the gully the snow was deep and soft and several abortive attempts were made to escape onto the rock. A little further up Melbourne and Smith successfully found a rock route, while Bratt leading our rope tried unsuccessfully to use crampons on the verglas covered rock in the gully. Melbourne and Smith moved up a steep rock buttress to a rock ledge then traversed south under a hanging block over 45° slabs to reach easier ledges leading eventually to the ridge on the summit side of the last large gendarme. Following the other two, Bratt and I decided after the first rock pitch, that perhaps crampons weren't the ideal footwear and lost fifteen minutes to the leading pair and didn't see them again until we reached the summit. It had taken nearly two hours to get free of this three hundred feet gully and we were glad to be on the easier going of the ridge.

The route we followed along the ridge was rather broken with shattered blocks, vertical buttresses and two gendarmes, of which one was turned on the east and the other traversed. With never a sight of the summit we continued up and down for one and a half hours until we came to the steep ice ridge, rising some two hundred feet to the summit. It was a typical north facing slope, ice hard and broken. After stopping to put on crampons, we finally sat on the knife edge summit with Melbourne and Smith at 11.45 a.m.

The weather had up to now been quite clear, but the clouds were beginning to boil up from the east and were already obscuring neighbouring peaks.

All four of us descended to the north west across the ice face (the ridge being far too broken), but after some three hundred yards Melbourne and Smith started a steeper descent. Their object was to return rapidly to the valley and continue the geological and survey work. Bratt and myself after food and rest continued north west along the ridge. Here as on the Matchu Suchi Coochi ridges we found the same curious U shaped trench between the rocks on the north and the glacial ice to the south.

Moving sometimes on the ice ridge, sometimes on the rock, but more often in the trench we traversed over a second peak and on down to a second col. On the way down we passed a split ice pyramid on the east. When viewed from the west this pyramid with its fifteen feet wide split had appeared as an insurmountable obstacle.

Past this the ridge continued to the north as a shambles of crevasses and humps so that we were forced to the deep soft snow on the west of the ridge. After making a circuitous crossing of a wide snow filled crevasse, during the crossing of which Bratt lectured on the recovery of a half suffocated victim single handed - most likely to be Bratt, we came out again on the eastern snow and rock. Here on the eastern slopes the snow lay in a hundred feet bed of 60° slope below which there was a six hundred feet drop to the glacier below. This went quite easily until about half the way across; we only had to contend with snow-balling up under the crampons. But the nearer we got to our peak the deeper and less stable the snow became. Things really began to worry us when the bottom of our steps, about two feet below where our legs disappeared into the snow, started pushing out and vanishing rapidly over the drop below. Bratt, who was leading, tried to carefully compact the snow before putting all his weight on each step as by now his only belay was my axe buried in the soft snow.

At last Bratt reached a pile of tilted rock slabs frozen to the ridge, but looking ready to slide at any moment into the abyss below, and gained a rock platform ten feet below the summit. The actual summit consisted of a heap of rotten ice which looked as though a few strokes of the axe would send the whole structure crashing to the valley below. We were content with our platform.

It was now 4.30 p.m. and the cloud had closed in completely around us. After some difference of opinion as to our route of descent we decided to abseil down the gulley directly below us. After dropping down some five hundred feet in six abseils we reached the glacier. Jumping, running and sliding over the snow and scree we reached the valley floor at 5.30. In the deepening gloom and thickening mist we trudged back to camp in a snow storm, reaching it at 6.30 and satisfied that we had climbed all the peaks on the Soral Este ridge in the past two days.

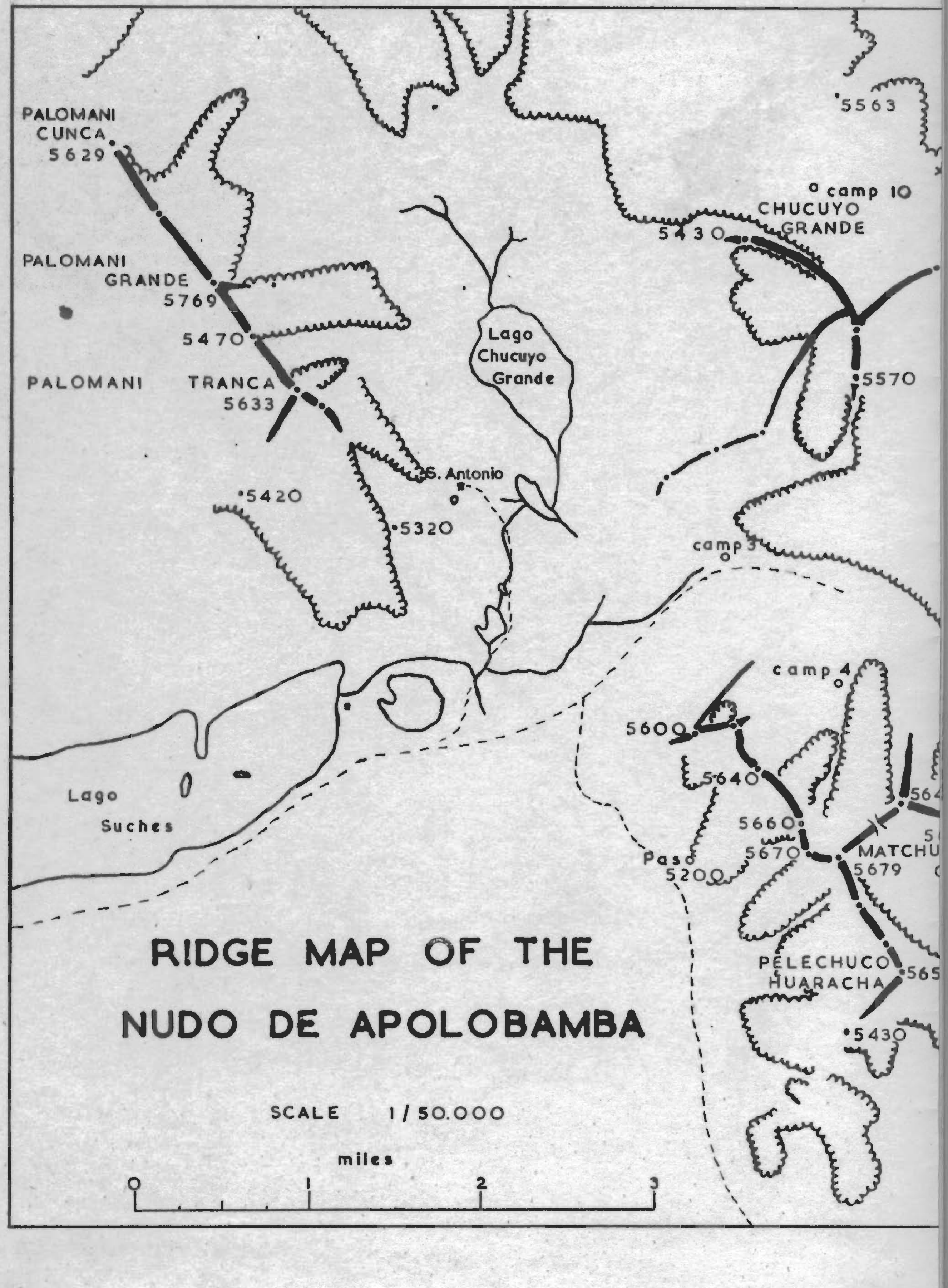
Mountaineering History of the Nudo de Apolobamba

The first recorded information concerning the Apolobamba is written in the Report of "The Peruvian Boundary Commission", 1911-1913, which records the work of fixing the principle peaks in the area as indisputable boundary marks. Although they did not enter the area with which we were concerned, their map proved invaluable.

The first real mountaineering trip to the region was in 1957 when a German expedition climbed Huanacuni, Cololo, Chupi Orco, Huelacalloc, and several subsidiary peaks. Their report together with a map is published in the (so far unseen) Deutsch Osterreichischen Alpenverein Jahrbuch 1957-58.

In 1958 an Italian expedition (C.A.I.) climbed all the peaks on the border together with Ananea and Calijon from north of Chupi Orco to Palomani Tranca. Some confusion arises because of their use of Italian names but their information was most useful to us. Their report is not published at the time of writing.

Additional information was obtained concerning the existence of Matchu Suchi Coochi from Dr. G. Francis "Invitation to the Andes" (Alpine Journal May 1953).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camp 10
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MATCHU
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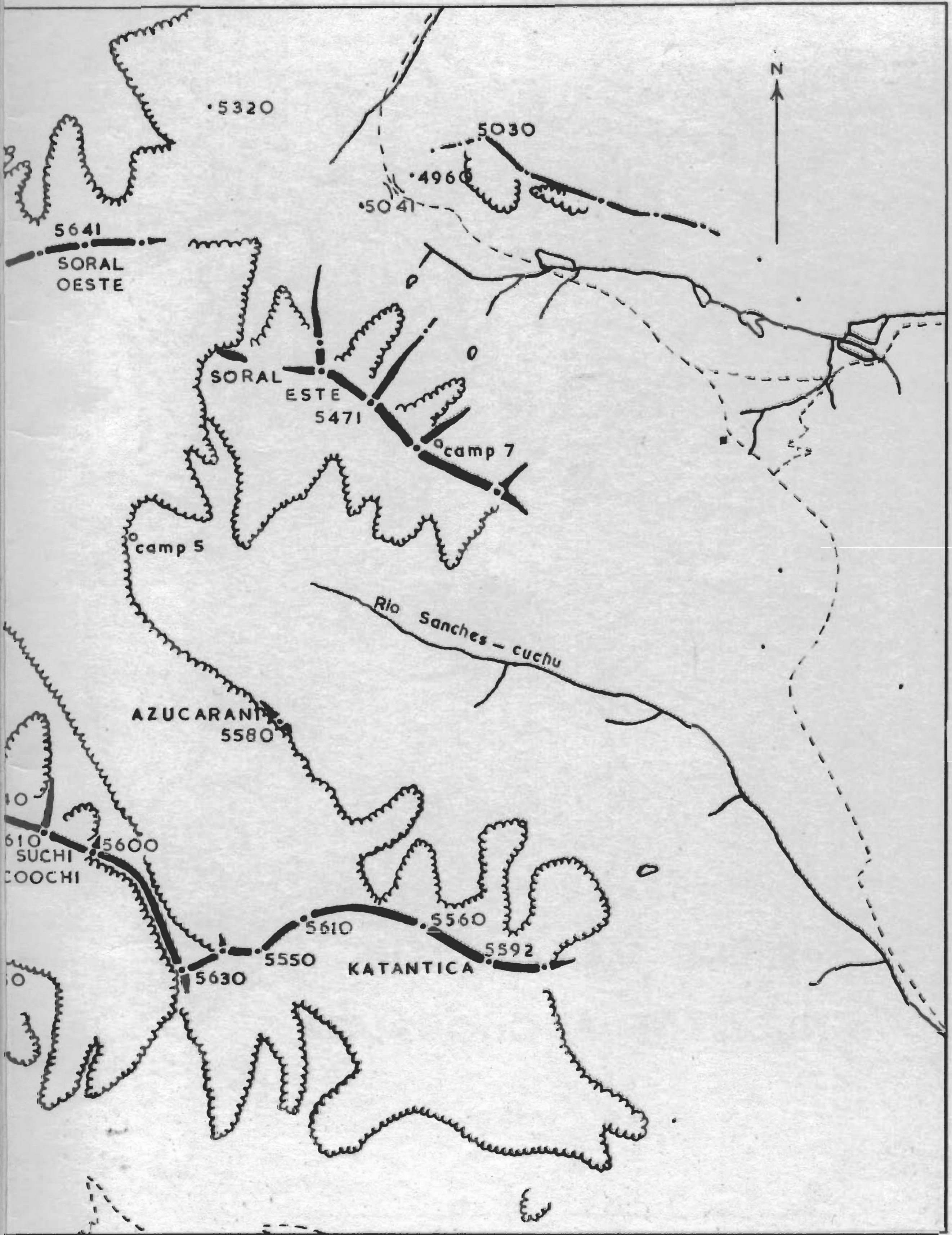

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SUCHI
COOCHI
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KATANTICA

11. Plant Collections G.C. Bratt

At the request of Dr. P.W. James of the Botany Dept. in the British Museum, a collection of plants, growing at high altitudes, was made. This collection included some 30 species of lichens and about the same number of flowering plants and grasses.

Lichens grow at all altitudes visited (up to 18,500 ft). Flowering plants were absent above 16,000 ft. although mosses and grasses persisted to 17,500 ft.

Grasses, mosses and algae appear to be the first colonizers of the moraines left by glacial recession.

The lichens so far indentified include:-

Psorama Sphintrinum (Mont.) Nyl.
" Dimorphium Malme.
x Peltigera Polydactyla (Neck) Hoffm.
x " Canina (L.) Willd.
" Spuria (Ach) D.C.
Cladonia Gracilis (L) Willd.
" Pyxidata (L) Fr.
x Newopogn Cibatas
" Auratiacoatia
" Sulpluyeus
x " Antarticus

x These species also occur in Patagonia below 5,000 ft. and so are not essentially high altitude types.

12. Equipment Details

J.W. Jenkinson

Organisation of the expedition equipment was begun in April 1958 by K.J. Hopkins, with the drawing up of a list of possible requirements and several tentative enquiries to camping goods manufacturers. October saw the construction of a modified requirement list and correspondence was opened with some 40 firms regarding their readiness to supply and the terms available for goods purchased by the expedition. Our use of certain equipment already in the I.C. Exploration Board was sanctioned and more definite arrangements made with specific firms.

In December 1958 when the expedition was financially sound, definite orders were sent out for major items. A delivery dead line was set for the 21st April when all equipment was to be at hand for packing, the freight collection date being 1st May. All firms were extremely cooperative in adhering to the stipulated date and every item had arrived by the time they were required for packing. Final cost of equipment was close to £290.

EQUIPMENT LIST

This list excludes survey gear

Where the terms are not given for a particular item, purchase was made at the quoted figure of the firm without mention of a reduction.

Item	Number of, per person (6)	Source or Firm Supplying,	Terms
Windproof jacket	1	Aquascutum Ltd.	Reduction
overtrousers	1 pr.	"	"
Boots	1 pr.	Balley Aeron Shoe Co.Ltd.	
String Vests	1		Free.
Underpants	1	Personal	---
Shirts	1	British Cellular Clothing Co. Ltd.	Free

Equipment List(Contd.)

Item	Number of per person (6)	Source or Firm Supplying.	Terms
Breeches	1 pr.	Personal	-
Socks-Long	2 pr	Wolsey Ltd.	Nominal sum
" -short	1 pr		"
-others		Personal	-
Sweaters-thick	1	Wolsey Ltd.	Nominal sum
-thin	1	"	"
Balaclava	1	Personal	-
Gaiters	1 pr	Personal	-
Goggles	1 pr	Personal	-
Watches	1	Smiths Ltd.	Free
Duvet jacket and hood	1	Alpcan	
trousers	1		
Gloves-balloon mitts	1 pr	Personal	-
silk inners	1 pr	Personal	-
ventile over-gloves	1 pr	Personal	-
Icelandic Special sleeping bags	1	Thos.Black & Sons Ltd.	Reduction
" " " inner	1	"	"
Air mattress, Lilo 'Tourist'	1	P.B. Cow & Co.Ltd.	Reduction
Rucksack, B.B. Pennine	1	Brown Best Ltd.	Reduction
Pack frames ex U.S. Army	1 + 2spares	Zimmermanns	
Kit bags ex W.D.	3	"	
10' Slings nylon	2	Personal	-
Karabiners	2	Personal	-
Glacier Cream	1	Savory & Moore Ltd.	Free
Medical kit	1	Personal, supplies from Boots	Free
Repair kit	1	Personal	-
Plastic bags	various	British Visqueen Co.Ltd. & I.C.I.	Free Free
Billies	1	Personal	-
Frypan (as lid & plate)	1	Personal	-
Knife, jack type, & spoon,	1 of each	Personal	-
Tin openers, baby type	1	Perdonal	-

	Number of		
Cups	3	Personal	-
Primus 1 pt silent	3	Board	-
½ pt roarer Optimus	1	Personal	-

Equipment List (Contd)

Item	Number of	Source or Firm Supplying	Terms
Torches and Spares	2	Everready Co.Ltd.	Free
Fuel bottles	8	Thos.Black & Sons.Ltd.	Reduction
Water buckets ¾ galls	3	"	"
Various food containers are specified in the food report			
Meade type tents in Ventile			
sleeve entrance with ventilations	2	Thos.Black & Sons Ltd.	Reduction
zip without vents.	1	"	"
B-Meade in millerain + flysheet	1	Board	-
120 full weight nylon climbing ropes	2	Board	-
200 ft ¾ weight nylon climbing ropes	2	Thos Black & Sons Ltd	Reductions
¾" hemp line 600ft	1		
Full medical kit	1	Boots Pure Drug Co.Ltd.	Free

The following is a more detailed exposition on certain major items of equipment. Personal items such as socks, etc., have been omitted as being more or less standard to mountaineers.

Windproof jackets and overtrousers were manufactured from rain-proofed Wincol. The jackets featured a full length zip and were loose enough to fit over duvet jackets. Under the conditions encountered the performance of jacket and trousers was entirely satisfactory; hoods attached to the jacket and folding into a small zipped pocket behind the neck, gave adequate protection in driving snow and wind. One criticism was the external pockets of the jacket, most of which had partly ripped away by the end of the expedition. Patch pockets would be far more durable. Two excellent pockets, however, were incorporated inside the lapels. Jacket, hood and trousers were lined throughout with nylon.

Fittings, for made to measure boots, were taken over two pairs of thick and one pair of thin socks, the boots incorporating 3-ply nylon insoles. In the field no one could wear more than two pairs of thick socks and initially two pairs of the boots were extremely tight across the toes. After one or two weeks these particular pairs of boots and one other pair became loose fitting around the heel resulting in excessive wear of socks. Hook fastenings gave good service but several top seams were beginning to come away after six weeks' wear.

Gaiters were of the elastic, hook fastening variety, being held down on the boot by two hooks, one in the laces the other in a cut in the boot strap. Only through slack laces could snow and stones gain access. All gaiters were still serviceable after six weeks in the field.

Overgloves in Ventile were little used. Silk gloves kept the fingers from getting too cold when manipulating the theodolite in cold, windy weather.

Full duvet gear was taken in anticipation of surveyors and geologists having to stand around working in cold windy conditions. However, in no instance were duvet trousers and hood required, duvet jacket and windproof overtrousers giving protection against the coldest wind encountered.

To combat the low temperatures that have been reported to occur at night double sleeping bags were taken together with hip length air mattresses. After a few days, inner bags, and in some cases the mattresses, were discarded to save weight and when a temperature of -2°F was experienced, camped on a glacier, using an Icelandic Special bag and air mattress, and wearing no more clothing over a sweater and breeches, no discomfort was felt. The short air mattresses weighed about two pounds each and as an experiment the author used a 1 inch thick foamed polyurethane sheet measuring 42" x 18", doubled back at the hips to give extra insulation. This mattress was contained in an open ended plastic bag and weighed three-quarters of a pound.

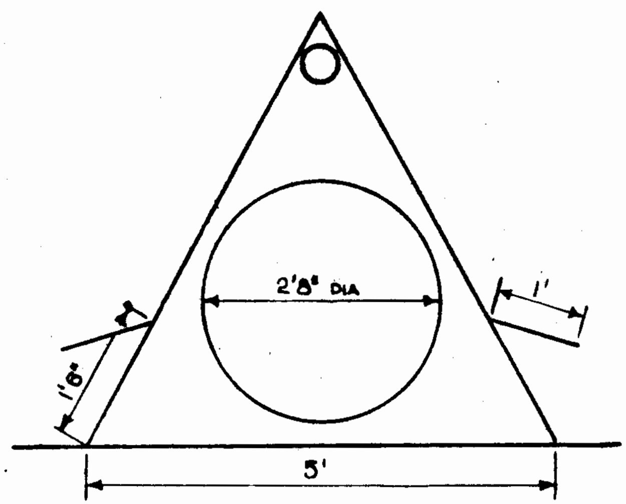
Fitting between shoulder and hip and augmented with kit bag and duvet jacket as a rest for the legs, it gave as good service as the air mattresses and could not let one down at inconvenient times.

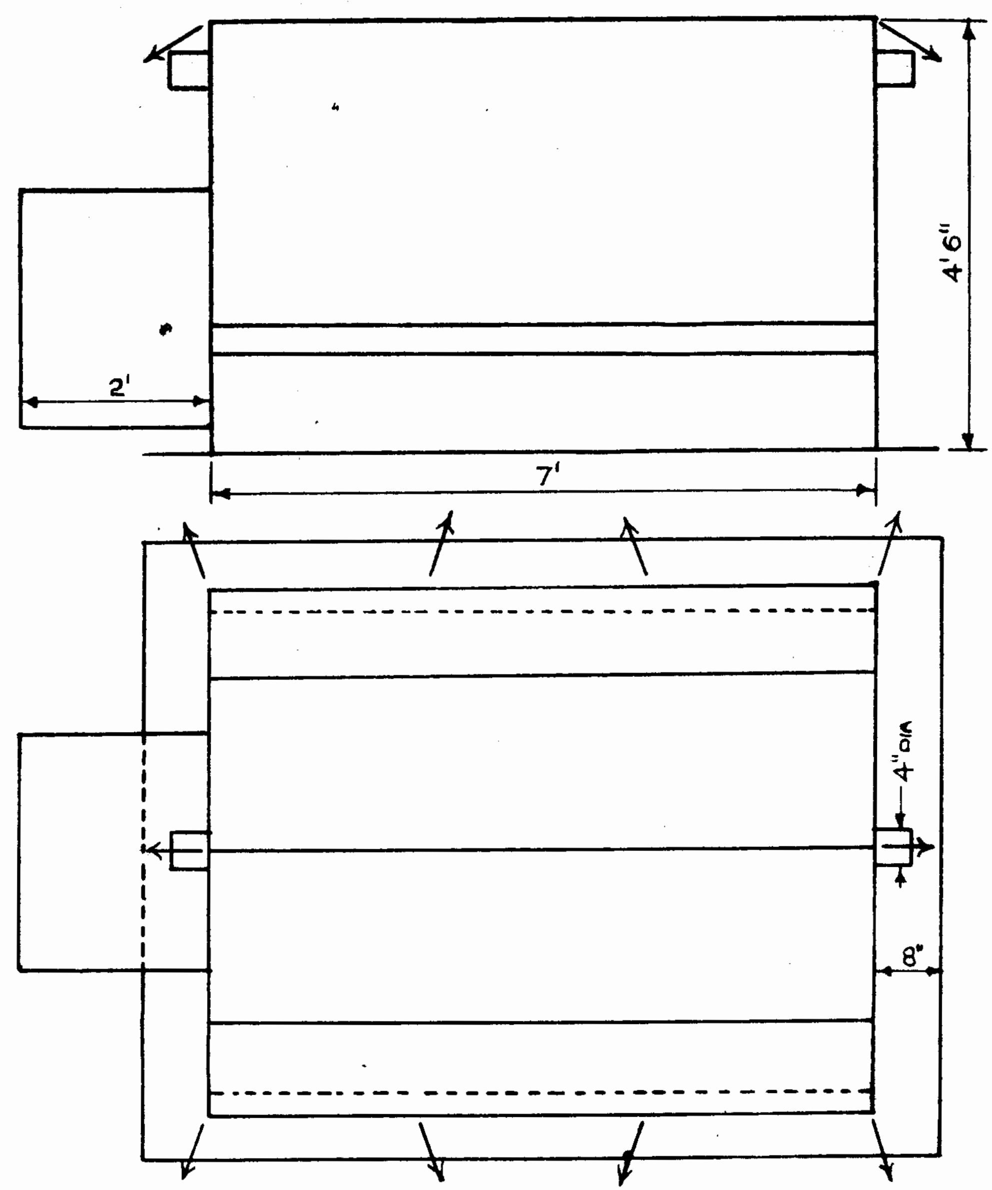
Kit bags and pack frames were taken as the most comfortable and versatile means of load carrying available. A larger quantity of kit bags could have been taken as the muleteers declared that tea chests were not suitable for mules to carry. The ideal would be to include sufficient bags in each chest to carry the contents.

The one pint Primuses were fitted with silent burners and worked satisfactorily throughout. A standard half pint Optimus worked satisfactorily at 16,500 ft. Meta fuel was taken as a primer but was soon discarded for its causing build up of unpleasant fumes in a confined space; the far simpler method of paraffin priming was adopted. A few minor troubles were had with stoves such as leaking pump valve washers, worn pump washers, and the blocking of nipples through the use of dirty fuel caused a continuous nuisance. A funnel incorporating a filter is recommended. Some notes on fuel consumption will now be given.

For the majority of the time cooking was done in pairs or four people on two stoves and fuel was consumed at the rate of one pint per four man days or, on one occasion when attemping the East Soral peaks fuel was in short supply and for some seven days the rate was a five man day per pint. However, the fuel consumption is considerably increased when melting snow. On the one occasion when it was required to melt snow and ice one pint lasted for a three man day at 18,000 feet. There is probably less tendency to heat water when camping on snow due to the tedium of collecting and melting snow and this latter figure may be subject to modification for prolonged camping on snow at this altitude.

Tents were designed by the expedition along Meade lines, the most interesting feature being A poles butting together in internal sleeves. Initially only two tents were ordered, with sleeve entrances and ventilators but later another tent incorporating a zip entrance and no ventilators was ordered. Made in Ventile L.34 the tents gave excellent service, although the sleeve entrances, narrower than was specified, caused annoyance. The cut of the walls gave a barrel shape and the design volume of the tents was considerably increased. With no ventilators and a zip entrance the air in this tent tended to get rather stale but this was outweighed by not having to crawl in and out, the whole end zipping out. Unfortunately the zip ~~worked~~ closed from top to bottom and it was not possible to have a top opening for ventilation without unzipping the whole entrance. In a wind it is doubtful whether this type of entrance would be rain and snow proof and the design could be improved by having a normal flap entrance fitted with a zip; (however zips are liable to freeze up). It is felt, that although essential for arctic conditions, a sleeve entrance is inconvenient for normal use. After camp 3, when the millerain B-Meade with flysheet was discarded, the Ventile Meades took three men with reasonable comfort when the occasion demanded. A sketch together with the original specification in included in the report. Weight with poles 15lbs.





TENT IN VENTILE L.34.

GROUNDSHEET IN DOUBLE-SIDED P.V.C.

JWJ

13. Food Details

A.W. Smith

Original Estimates

The original estimates of the quantity of food that would be required were based on a provision of 2 lb. per man per day. The total amount of food was to last six men for fifty days, plus an extra allowance for two Bolivians who were expected to be with us for part or all of the time. Obviously such bulk estimates could only be made for those items which would be in regular daily use, such as meat, vegetables, sugar etc. The remaining items (jam, marmite, salt etc.) had to be estimated on a weekly basis to cover a period of seven weeks.

Table I is a list of the original estimates (i.e. food taken on the expedition) together with the size of containers used. The table also includes a column of revised food estimates which is based on the field experience.

The total weight of food amounted to approximately 500 lb., which was less than the original limit of 600 lb. This defficiency could well be afforded since a fair proportion of the food was in dehydrated form. However, with as much weight as 500 lb. it was necessary to consider the possibility of purchasing certain goods in La Paz in order to avoid the added cost of freightage to Bolivia. Inquiries confirmed that prices in Bolivia would not be vastly different from those in England, and it was therefore decided to buy the following goods in La Paz:-

Item	Weight
Sugar	112 lb.
Rice	20
Salt	5
Coffee	10
Cheese	6
Bacon	10
Jam	5
Flour	6
Tea	2

TABLE I

ITEM	Actually taken: Wt./ Man/ Day	Actually taken: Total Wt.for 300M./ Days	Revised estimates: Wt./ Man/ Day	Revised estimates: Total Wt.for 300M./ Days	Types of Containers Used	Size of Containers Supplied
Dehydrated Ham	3oz			8lb	Tins	1 lb
" Minced Beef	"	6lb	3oz	16	"	"
" " Pork	"			16	"	"
Dried Peas		5		-	Plastic bags	
" Beans		4½		3	"	
" Onions	3oz	2		2½	"	
" Carrots		2½	3oz	-	"	
" Cabbage		4½		3½	"	
" Potato Strips	1oz	2		18	"	
" " Powder		19		-	Tins & Plastic bottles	11oz
" Apples		2		-	Plastic bags	
" Apricots	2oz	20	3oz	30	"	
" Bilberries		5		-	"	
Emergency Bar Ration	1½oz	6	3oz	10	Tin Foil	7oz
Corned Beef	3½oz	42	-	-	Tins	7oz
Soup Powder	½pkt	96pkts	½pkt	19 (100 pkts)	Foil packets	3½oz
Lifeboat Biscuits	4oz	84	2oz	63	Tins	7lb
Powdered Milk	2oz	30	3oz	30	"	2lb
Oatmeal Blocks	2oz	25	-	-	"	10oz
Dried Egg Powder	1oz	10	1oz	10	Plastic bags	
Sultanas		10	-	-	"	
Sweet Biscuits	2oz	20	-	-	Tins	
Margarine	1oz	30	1oz	27	"	8oz
Dates		5	-	-	Paper Wraps	
Marmite		2½	-	-	Tins	
Oxo		6	1oz	7	Plastic jars	
Honey		6	-	-	Tins	1 lb
Jam	2oz	5	-	-	"	1 lb
Syrup		14	1oz	20	"	1 lb
Peanut Paste		4	-	-	Plastic Jars	
Cheese		6	1oz	6	Plastic bags	
Sauce		1½		1½	Plastic jars	
Curry Powder	½oz	1	½oz	2	Tins	1 lb
Salt		5		1	Plastic jars	
Pepper		¼		¼	Tins	1oz
Fudge Bar	2oz	5¼	3oz	15	Tin Foil	6oz

TABLE I Contd	Actually taken		Revised estimates			
Item	Wt/ Man/ Day	Total Wt.for 300M,/ Day	Wt/ Man/ Day	Total Wt.for 300 M/ Day	Types of Containers Used	Size of Containers supplied
Kendal Mint Cake	3oz	45	3oz	30	Paper Wrap	3oz
Boiled Sweets	1oz	21	½oz	12	Plastic Bags	
Robinade	½oz	18	1oz	20	Tins	1 lb, 8oz 4 oz
Oats	2oz	20	3oz	25	"	1¼ozs
Tea		2	-	-	Cardboard Packets	¼ lb
Sugar	3oz	112	8oz	112	Sack	
Coffee	½oz	10	½oz	10	Paper packets	5 lb
Rice	3oz	20	3oz	35	Sack	
Ovaltine	1oz	6	1oz	10	Tins	2 lb
Bacon	1oz	10	1oz	10	Sack	
Flour	2oz	6	2oz	6	Paper bags inside plastic bags	
Miscellaneous						
Tobacco)	Personal				Screw-vac tins.	
Cigarettes)					Tins	
Pot scourers	6				-	
Toilet paper	6 rolls				-	
Wet ~~proof~~ Proof	12 tins				Tins	
Boot Polish	12 tins				Tins	

The next step was to approach all the firms and companies in an effort to find which of them could offer any reductions from their normal listed prices. In this respect most firms were very co-operative - not only economically, but also in their advice on the portability etc. of goods.(See Appendix I). This stage was reached by December 1958 and in many instances this was necessary in order to allow firms to arrange for the special preparation and delivery of their goods to fit in with their normal production schedule.

Food began to arrive at Imperial College as early as February 1959, and by April 10th (the deadline given to the firms) all food was ready for packing. This date may seem early but it must be remembered that the food had to be freighted to Bolivia on May 7th to allow for the expected delays in shipping and especially the customs offices in Bolivia. This point should be borne in mind by any proposed expedition - for delay at customs can be considerable and could easily put all schedules behind.

Use of the Food in the Field

a) Containers - The different varieties of food taken into the field proved to be more than adequate - especially for the short period of six weeks - and any expedition entering the field for a similar period could well afford to take a much simpler diet. This would have the desired effect of greatly reducing the number of containers needed to be taken into the field. At times it was found that up to 25% of the weight of food being carried was taken up by the weight of tin containers alone. Some goods, such as margarine, must of necessity remain in tins and two suggestions are made which would help to reduce the weight of container; food ratio:-

i) Use the largest containers possible within the practical limits of the expedition. Margarine, for example, was supplied in 8oz tins which lasted usually for two days only. A 1 lb tin would have been better.

ii) Use containers of aluminium or aluminium alloys whenever possible. Firms rarely supply their goods in such containers and it may therefore be necessary to personally transfer the goods in London before freighting.

The possession of tin containers proved to be valuable, however, on one occasion when the team had to leave base camp for a fifteen day sortie. Because a few Indians frequented the area near the base camp it became necessary to bury the bulk of the food supply that was left behind. But for the tin containers, this would have been virtually impossible.

b) Menus - During the first two or three days above 15,00 ft. several members suffered from bad headaches and vomitting with consequent loss of appetite. Within a week, however, all appetites had regained their normal proportions and daily meals followed a fairly regular pattern:-

Breakfast:	Oats; scrambled egg; 1 rasher of bacon; 2 cups of coffee
Mid-day (in field):	1 bar of kendal Mint Cake.
Upon return from field:	Biscuits with Marmite or honey; Robinade
Evening Meal:	Soup; half a tin of Corned Beef; vegetables or potato powder; fruit or rice; Ovaltine.

There were no wide variations on this diet except for the rare occasion when a vicuna (of the Llama family) was caught, and steaks became the food of the day. In the second half of the field period, pancakes became a favourite addition to the evening meal.

Several items on the food list turned out to be outstanding successes, the noteable ones being 1) Rum Flavoured Fudge Bar (by Horlicks), 2) Dried Egg Powder, 3) Emergency Bar Ration (Horlicks).

1) Rum Flavoured Fudge- was used as a mid-day snack on climbing occasions. The only regret was that more had not been taken.

2) Dried Egg Powder - was used practically every morning in the form of scrambled egg which was easy to prepare and very palatable. The powder had the added advantage of being useful for other dishes - e.g. pancakes.

3) Emergency Bar Ration - The bar ration is a solid concentrated preparation of mixed stew and is used in the field by heating with a little water. (Extra water turns the stew into soup.) Its inclusion as an emergency bar is well worth while, for in extreme emergencies it can be eaten dry - as proved by two members on one occasion. One bar, wrapped in tin foil, weights approximately 7 oz. and with the addition of potato powder or boiled rice is enough to constitute a main meal for four men.

c) Comments - A list of comments on some of the main items used is given below.

1) Dehydrated Vegetables. On the whole these were worth taking for the variety and volume they provided, but the

quantity could have been greatly reduced. Peas were disliked generally - mainly because they cooked badly - and different people had other dislikes. In order to avoid the accumulation and wastage of all the unliked types of vegetable, the various sorts were mixed together. This had the advantage of reducing the number of bags needed and therefore facilitated transportation.

Another disadvantage of the vegetables was that they needed 40 minutes boiling before they were palatable. Thus considerable time and fuel is taken up in cooking the vegetables alone. Some cooking time can be saved by soaking the vegetables for 4 or 5 hours beforehand, but this in itself is an added inconvenience - especially when camping on glaciers.

2) Corned Beef. Very well-liked, but it is exceedingly heavy and bulky. The ideal meat is the dehydrated variety (though the flavour was not liked by all) but unfortunately this was unobtainable in Britain at the time of the expedition. An expedition not wishing to carry the excessive weight of Corned Beef would be well advised to try and obtain dehydrated meat and to rely to a much greater extent on the Emergency Bar Ration (plus curry powder!)

3) Kendal Mint Cake. This item was relied upon rather too heavily as a snack at mid-day, with the result that half the members tired of it long before the expedition was over. It has the value, however, of a high calorific content and is difficult to replace by something of equal value, size and weight. The Rum Flavoured Fudge (Horlicks) bar would be an ideal substitute, though it is twice as expensive. Chocolate (if bought locally) would also make a good change; considerable trouble has been experienced in taking chocolate from England through tropical climates.

4) Dates. Too sticky to carry about.

5) <u>Oatmeal Blocks</u>. Hardly worth carrying due to their weight.
6) <u>Tea</u>. Could well do without it for further simplicity of food list.
7) <u>Jam, Honey and Peanut Paste</u>. These are entirely luxury items and cannot be transported once they have been opened (unless they are transferred to plastic jars).
8) <u>Flour</u>. Not absolutely essential, but proved to be a good stand-by.
9) <u>Sauce, Curry Powder and Pepper</u>. Well worth including for their value in livening up the meals.
10) <u>Dehydrated Potato Strips</u>. Although bulkier than potato powder, the strips have the advantage of making excellent chips which make a pleasant change. The powder, on the other hand, may be prepared as potato mash in the evening and then fried for breakfast on the following morning. For simplicity it would be better to take one variety of potato only, and the potato strips are to be preferred.

Two important conclusions can be drawn from the experience gained in the field and they may be summarized as follows:-

a) The expedition could have easily survived on a much simpler diet over the short period of 6 weeks - and longer if necessary. A simple diet facilitates packing and handling of food and consequently gives greater mobility to an expedition. Luxury items (jam, honey etc.) are better left behind.

b) Wherever possible all tin containers should be avoided and substituted by strong polythene bags and sacks.

For an expedition requiring high mobility over a short period (up to three weeks), the following list is given as an indication of the bare essentials which would suffice - providing the participants were not fussy over change of diet:-

Item	Quantity per Man-day
Various dehydrated meats and Emergency Bar	4 oz
Soup powder	1
Curry powder) Salt)	½
Powdered Milk	3
Rice	4
Oats	12
Sugar	8
Rum Fudge	3
Coffee	—

APPENDIX I

ITEM	FIRMS APPROACHED	NORMAL RETAIL PRICE (1959)	TERMS
Dehydrated Ham " Minced Beef " " Pork	Min. of Agric. Fisheries 7 Food Aberdeen		
Corned Beef) Oxo)	Thames House, Queen St.Place, E.C.4.		Full price
Dried Peas) " Beans) " Onions) " Carrots) " Cabbage) " Potato Strips) " Apples) " Bilberries)	Templeton Patents Ltd., Tatmore Place, Gosmore, Nr. Nitchin, Herts.		
Dehydrated Potato Powder) Robinade)	J.& J. Colman Ltd., Harrow Works,Norwich.		Full price
Margarine	Van den Berghs Ltd.,43 Fetter Lane, E.C.4.		
Kendal Mint Cake	Geo. Romney Ltd. Waterside, Kendal, Weston.		
Emergency Bar Ration) Rum Flavoured Fudge)	Horlicks Ltd., Slough, Bucks.		
Boiled Sweets	Pascalls Ltd., Mitcham,Surrey.		
Powdered Milk	Glaxo Laboratories Ltd., Greenford,Middx.		
Oats	Scotts Porridge Oats.		
Lifeboat Biscuits) Sweet Biscuits)	Parr and Co. Ltd., Carlisle.		
Oatmeal Blocks	Huntley & Palmers		
Dried egg	Felton & Crepin Ltd.,15 Coopers Row, E.C.3.	8/- per lb.	Full price

Honey	Chivers & Sons Ltd., Orchard Factory, Histon, Cambridge.	
Syrup	Tate & Lyle Ltd., 21, Mincing Lane, London, E.C.3	
Sauce		
Ovaltine		
Coffee) Bacon) Cheese) Sugar) Rice) Jam) Flour) Tea) Salt)	Obatined retail in La Paz, Bolivia	2/3 per lb) Full 5/3 ") price 7/- ") 7d ") 10d ") 3/10d ") 7d ") 5/- ") 5d ")
Dried Apriconts) Dates) Curry Powder) Pepper) Pot Scourers)	Bought Locally	Full price
Cigarettes) Tobacco)	W.D. & H.O. Wills Ltd., Bedminster, Bristol 3	Free
Wet Pruf) Boot Polish)	Kiwi Polish Co.(pty) Ltd. London, W.5	Free
Soup Powder	a-Bought Locally b-Batchelors Soups Ltd. Sheffield 6.	1/6 per packet Free
Peanut Paste		
Sultanas	Australian Dried Fruit Board, Ocean House, London, E.C.3	

14. Travel and Transport Arrangements. P. Garrard

Three factors had an important effect on the travel arrangements - distance to Bolivia, college examinations and the Italian seamens' strike. Because of the time required to reach Bolivia and the timing of college examinations it was necessary for the party to split and a rather complicated itinerary used. The seamens' strike and the highly unsatisfactory negotiations with the Italia Line could have wrecked the expedition.

Ewart who was to work with the British Museum expedition in Peru for a few weeks before joining the main party was to travel by ship to Rio then by air to La Paz. Bratt and Melbourne were to chase the baggage by travelling by ship to Arica, Garrard, Jenkinson and Smith, whose examinations did not finish until June 19th, were to use the same route as Ewart. Final bookings were made on March 19th through Sewell and Crowther (Travel Agents). These arrangements are detailed in Table 1. From La Paz to the mountains the transport was to be truck arranged by Sr. G. Farwig of the C.A.B.

These simple arrangements were thrown completely out of gear when on June 9th the Italian seamen struck; all Italia Line vessels in port at the time stayed there, those at sea continued only as far as the next port.

Ewart found himself stranded in Daker (W. Africa) and had to stay there for 9 days before being flown by Italia Line to Rio de Janeiro. These flights came only under the stress of a demonstration by the passengers. Likewise, Bratt and Melbourne were in Cannes without a ship. Their position was in some ways worse than that of Ewart, because Italia Line accepted no responsibility for passengers who were not en route and it was entirely by their own efforts that they found berths on board the "Bretagne" sailing from Marseilles to Rio. Smith, Jenkinson and Garrard, were still in London. From here, again with no assistance from Italia Line, berths were secured on the "Highland Brigade" sailing from Tilbury to Rio. It should be noted here that the Travel Agency knew about the strike a week or so before they told the party. The first information was a letter received from Dakar on June 17th. It may be asked why a British ship was not used in the first instance. The answer to this lies firstly in the chariness of Pacific Steam Navigation Co. to commit themselves to a fixed schedule, and secondly in the fact that Italia Line give a 10% reduction on the total fares for passengers traveling on both outward and return journeys. This reduction they agreed to grant, even with the transfer of passages to the "H. Brigade".

Because of this delayed arrival in Rio, Ewart was not able to obtain a flight booking for 5 days. A further two days was spent at Corumba, because of bad weather, and a week at Santa Cruz dodging the bullets of revolutionaries put his arrival in La Paz into early July - much too late to join the British Museum expedition. Nine days later, Bratt and Melbourne flew in from Rio, having experienced similar difficulties in obtaining a flight, whilst to complete the picture the third party found that their flights from Rio were on the 11th, not 10th, and that only two of these were available. On returning from Sao Paulo, it was learnt that the flights were now on the 14th.

It is no exaggeration to say that travelling arrangements to, from and in the mountains were more closely fulfilled than any in the more civilised world. Trouble was experienced, however, with the procurement of mules. On 14th July, Melbourne and Caraffa arrived in Pelechuco, to be told that no animals were to be had there. For the whole of the next day the village was engaged in fiesta, but later during the day it was intimated that five might possibly be available the next morning. At 9.00 a.m. none had been brought and it was not until 1.00 p.m.

on the 16th that seven mules were eventually hired.

On 28th July, Sr. Farwig arrived at Suches with mail etc. The Italia Line strike had finished and the new schedule showed vessles calling at Arica on August 27th and September 15th. On the strength of this information and in order to forfeit as little as possible of our working time, it was decided that Ewart, Melbourne and Garrard, who wished to be in London by the first week in October, should transfer to the "Reina del Mar" (P.S.N.C.) leaving Arica on August 31st. The others would return on September 15th on an Italia Line ship.

On 24th August, Sr. Farwig made his second visit, this time with the news that Italia Line schedule was again altered so that the September 15th vessel now sailed on September 29th. Clearly it was out of the question to catch this. Moreover, the transfer to "Reina del Mar" was effectively stopped by Italia Line:- 1) not honouring an agreement with P.S.N.C. allowing free transfer of passages (they asked 10% cancellation fee), 2) demanding the forfeiture of their Return Fare reduction and 3) as a consequence making the fare on "Reina del Mar" a further 130 dollars (£46) per person to pay. Sr. Farwig had booked six berths on the "A. Vespucci" to be confirmed by telegram. The journey down from the mountains was made on August 25th seven days before planned.

This was not the end of the trouble. Italia Line informed the party of August 27th that only First Class berths were available. Despite this, the party decided to fly to Lima on the chance of getting aboard and at 7.30a.m. on August 31st we were at the doors of the Italia Line offices in Lima.

The effect of these vacillations on the part of Italia Line is almost incalculable. The plane-table survey was not even commenced in one area because of lack of time, Ewart was unable to go to Macusani; whilst over £350 of unforeseen expenditure included flights to Lima, telegrams etc. Luckily all members of the party arrived in La Paz close to the original schedule.

The inconveniences caused us were communicted to Italia Line offices in London quite soon after boarding the vessel.

The party arrived in Barcelona on September 25th and reached London on the night of the 27th.

	Planned	Actual	Planned	Actual	Planned	Actual
	A.Ewart		G. Bratt & W .Melbourne		A.Smith, J.Jenkinson, P.Garrard	
June 1						
2	dep.London	dep.London				
4	emb. Barcelona	emb. Barcelona				
7			dep. London	dep. London		
9	Dakar	Dakar				
12				arr. Cannes		
14			emb. Cannes			
15	arr.Rio			Cannes-Marseilles		
16	Rio-Corumba					
17	Corumba-La Paz					
18		Dakar-Rio				
20				dep. Marseilles		dep. London
23		Rio-Corumba				
24					dep. London	
25		Corumba-Santa Cruz				
26					emb. Barcelona	
July 2		Santa Cruz-La Paz		arr.Rio		
6						arr.Rio
7			))arr.)Callao)	Rio-Aquiduana		Santos/S.Paulo
8				Aquiduana-Corumba	arr.Rio	
9						S.Paulo-Rio
10			arr. Arica	Corumba-St. Cruz	Rio St. Cruz	
11				St. Cruz-La Paz	St. Cruz-La Paz	
14						Rio-Corumba
15						Corumba-La Paz

II Transport

Arrangements for finding a cargo vessel were left to Sewell and Crowther's Freight department in Bishopsgate and from them we received much help with regard to Customs requirements and formalities, but it was extremely difficult to pin them down to giving a definite date of sailing and, more importantly, arrival in S. America. To illustrate this, the following is a quotation from a letter received:

> "The S.S. "Santanter" is expected to sail from London on May 7th arriving Arica June 9th .....
> ... This should give time for Customs' clearance and arrival at La Paz before July 10th."
> (My underlinings)

In fact, the Santander did not sail on May 7th, but later; and in the end the freight was shipped on board the "Kenuta" (P.S.N.C.) which left Liverpool May 7th and arrived Arica June 11th.

During the last few days of April, food and equipment was packed into tea chests of volume five and three cubic feet, which were then steel-banded for safety. This seems to have been a quite successful method, for only one mishap occurred en route, resulting in the loss of about ten small tins of corned beef. There were in the end 5 crates of equipment, camping, surveying and personal; and 10 of food. These last comprised five food dumps and contained carefully worked-out quantities of different types of foods. Easily-spilled articles such as dehydrated vegetables were weighed into polythene bags which were further packed into tins. Final gross weights varied between 50 and 80 lb. and on two adjacent sides was stencilled the name of the expedition, its destination and port of arrival, "En transito para Bolivia", a consecutive numbering and net and gross weights. The chests were collected on May 1st.

Customs' requirements (in additon to the labelling above) comprised a list of the contents of each chest with the value of each article.

Certain dutiable articles, namely cigarettes and toabacco, boots and duvet equipment were to be held in bond until the cargo vessel sailed; and the Port of London Authority Wharehouse in Cutler Street agreed over the 'phone to serve as a temporary store until, P.S.N.C. decided upon the house for their vessel. However, when the duvets arrived at London airport they were rejected by P.L.A. for over a week. Eventually they were taken and it was possible for Ewart to take his own suit (and boots) and repack them for collection as he passed through Newhaven. It was emphasised that this was not normal procedure.

There was some doubt as to whether the Bolivian Government would charge an import deposit on the photo-theodolite and other surveying equipment and for such a possibility and also to cover freighting costs from Arica to La Paz a debit account was arranged in England. However the Government granted duty-free entry of equipment.

On arrival at Arica on June 11th the freight became the responsibility of Velho and Co., agents to Sewell and Crowther. They were to guide it through Customs and then hand it to the British Embassy in La Paz for storage until our arrival. One month was not sufficient, however, for this. Blame rests on the Customs who, in a country of low wages and inflationary currency are loth to exert themselves in the absence of a money incentive. The continual prodding by the British Embassy eventually released the freight on July 11th.

Freight is carried by the "Ton weight or measurement", i.e. 20 cwt or 40 cu.ft. whichever is the greater. Since 40 cu. ft of tinned food approximates to one ton, most of the crates were judged by volume. The estimated cost calculated from the charges of:-

Foodstuffs	345/-per ton
Medical stores) Equipment)	440/-per ton

came to the region of £340 whereas the bill presented to us amounted to ~~almost~~ double this £100 ~~£275.~~ The difference arises from charges by the agents for their own services and for those of sub-agents. This point should not be overlooked in future estimates.

A final point regarding mules may usefully be made. The cost of hiring these was 20,000 Bolivianos (12/-) per mule per day and 10,000 Bolivianos (6/-) for the services of a muleteer. The size of tea chest, which held about 60 lb., had been chosen with the possibility in mind of our having to carry them on pack-frames. This was a very awkward size for the mules, which were not equipped with proper saddles. The answer lies in taking sufficient empty kit bags in the top of each chest to hold the contents and then repacking in these.

15. Notes on Political Formalities A. Ewart

During the preliminary organisation in November 1958, both the British Council and the British Foreign Office (Latin-American Dept.) were approached with the proposed plans and arrangements of the Expedition. Unfortunately, the British Council have no office in Bolivia, and so could not be of any direct help. The Foreign Office, however, undertook to obtain formal permission from both the Bolivian and Peruvian Governments for the Expedition to visit and undertake scientific work on their common border. Formal permission was duly granted, from Bolivia in February and Peru in April. In addition, permission from the Bolivian Government to enter the stores and equipment free from Customs' duties and taxes, was also obtained. The permission in each case was obtained by the Foreign Office through the respective Embassies in La Paz and Lima.

In addition to the above formal permission, normal tourist visas for Bolivia and Peru were required by each member of the Expedition. Further transit visas were required for Brazil and Chile, as the travel arrangements involved travel through these countries. The visas were obtained from the appropriate Consulates in London.

16. Medical Report

A.W. Smith

Preparation

It was decided early in the expedition planning that a medical officer would not be necessary. This step avoided the expense of taking an otherwise redundant member, but also meant that the team had to be prepared to cope with all possible ailments or accidents. Two members had already received training in First Aid and the remaining four members took a course of six lectures in First Aid at the Royal School of Mines. Thus it was hoped that should any member break a limb or receive a bad wound, then any of the remaining members could attend to him until he could receive proper medical treatment.

Enquiries made at the various embassies and travel agency revealed that the following injections were advisable:-

1. T.A.B. (Cholera and para typhoid)
2. Smallpox.
3. Yellow Fever.

These were taken by every member who had not been previously innoculated.

Besides this preparation for major accidents, one had to safeguard against all types of minor ailments which, if left untreated, could have become serious. In this respect we had a good deal of guidance from Dr. G. Budd who accompanied the 1957 Karakoram expedition.

The intention was to split the expedition into mobile, self-contained units which would return to a base camp at intervals. For this purpose it was decided to issue each member with a small personal medical kit and to keep another medical kit for wider needs at base camp. The Imperial College M.O., Dr. Gray, was asked for advice as to those items which would be essential for the trip, and with this and other information, a provisional list of medical equipment was compiled. An approach was then made to Boots Pure Drug Co.Ltd., Nottingham, who are to be thanked considerably for providing advice and information on the form in which the items would best be taken. This added information produced a final list of equipment which was generously donated by Boots.

TOTAL MEDICAL KIT:

6 x 30	Alimex tablets for indigestion
3	Magnet insect deterrent powder
10 x 100	Soluble Aspirin tablets
1 x 100	Quinalbarbitone tablets. gr ¾
5 x 100	Phthalysulphathiazole tablets 0.5 g. for dysentary.
8 tins	Gee's Linctus pastilles for coughs & sore throats
8 fl.oz	Gee's Linctus liquid
6 tins	Strepsil lozenges for high altitude cough and sore throat
100	Tablets of Calcipen - V 125 mgm (oral Penicillin)
12 large size	Burnol cream - a general antiseptic & acroflavine for burns
6 x 100	Halazone tablets for sterilising water
2 bottles	Viso Eye drops
100	Cascara tablets gr 2 - laxative
12 tubes	Mylol cream - an insect repellent
100	Chloroquine Phosphate tablets 0.25 g - an antimalarial
5 x 100	Plurivite tablets - vitamin pills
3 tins	**Mycota powder - for ahtletes foot**
3 tubes	**" cream - " " "**
12	Emergoplast 3½"x 4½"
12	" 1½"x 2½"
1	First-Aid case No.44
4	Vic B.P.C. Crepe Bandage 5" wide
12	Compressed Absorbant Wool ½ oz.
6	No.14 Medium plain Wound Dressing
6	No.13 Small " " "
3	Traingular Bandages 51" x 35"
18	Absorbent Gauge ¼ yd.
3	Regaid Elastic Adhesive Bandage 3" x 3 yds.
4	" Zinc Oxide Adhesive Plaster 5 yds x ½" wide
2	Regaid Zinc Oxide Adhesive Plaster 5 yds x 1" wide
1	Clinical Thermometer - ½ minute

In addition to this list, the following items (kindly donated by I.C.I. Ltd. (Pharmaceuticals Division) were taken:-

8 tubes	Savlon antiseptic lozenges (throat & mouth infections)
10 phials	Crystalline Penicillin (Na Salt) for septic wounds
6 tubes	Cetavlex antiseptic cream

From this total list, the following items were selected to constitute the personal medical kit for each member of the expedition and were issued before leaving England:-

100	Aspirin tablets
15	Quinalbarbitone tablets
60	Pthalylsulphathiazole tablets
1 tin	Gee's linctus pastilles
1 tin	Strepsils
1 tube	Burnol cream
100	Halazone tablets
15	Cascara tablets
1 tube	Mylol cream
100	Plurivite tablets
1	Emergoplast 3½ x 4½
2	" 1½ x 2
1	Compressed Absorbent Wool - ½ oz.
1	No 14 Medium plain wool dressing
1	No 13 Small " " "
1	Absorbent gauze
1	Regaid Zinc Oxide adhesive plaster 5 yds x ½"
1	Phial of crystalline Penicillin
1	Tube Savlon lozenges
1	Tube Cetavlex cream
1	Tube glacier cream

Use of the Medical Kit

a) Personal Kit - The effects of reaching the height of 15,000' within 48 hours from sea level were felt by every member. Everybody suffered from violent headaches during the first two or three nights, but some relief was found by taking two or three aspirins and occasionally a tablet of quinalbarbitone before retiring. Three members also suffered from vomitting, but this only lasted for the first day. Within three days the worst effects had passed, although there were one or two lingering headaches up to 7 days afterwards.

A more permanent feature caused by the altitude was the breathlessness which everybody felt during exertion. Even at the end of the six week field period, this effect was still present - though slightly reduced.

From the start of the field period every member began a regular course of two vitamin tablets per day. This was more of a precaution measure, since the diet was fairly well balanced to begin with. If a harsher diet of more simple food had been in use for longer periods, (as recommended in the food report,) then the vitamin pills would have been of much greater necessity.

The sudden change to the expedition diet of dehydrated goods is thought to be responsible for the nine day lack of defaecation experienced by one member. Ultimately, and with the aid of two cascara tablets, his condition returned to normal. Apart from this there was only one item in the diet which had important physiological effects. This was the bacon fat which was used in increasing quantities towards the end of the field period for frying pancakes and potatoes. At one point it was used heavily for four successive days and on the fifth morning one member,- vomitted the whole of the previous evening's meal - apparently completely undigested. During the following 36 hours he also suffered from acute diarrhoea and further slight vomitting. Two other members had diarrhoea on the 7th day and also suffered from very bad indigestion. It was found later that indigestion was a fairly common complaint after eating a lost of food cooked in fat.

Throughout the expedtion almost every member was affected by minor cuts - received mainly by slipping on scree slopes. Such cuts were treated, where necessary, with either Burnol or Cetavlex cream, and within a few days the cuts were healed. This was very satisfactory, for it had prewiously been a common experience for cuts to remain open for excessively long periods - due possibly to the cold at high altitude.

Sore throats were developed by two members of the team, as a combined result of the very dry air and dust which was disturbed when camping on glacial moraines. Strepsil lozenges were taken regularly during the day and after three days the soreness had disappeared. At night the Gee's Linctus lozenges were preferred since they also provided a certain inducement to sleep.

Apart from the first few days during acclimatisation, insomnia was most uncommon - even though night temperatures were below freezing point. Only when the temperature reached below $0^{o}F$ was sleep disturbed, but this only happened on one occasion.

The Halazone water sterilising tablets were frequently used when camping in the valleys. This was because the water had often to be obtained from rather stagnant, boggy areas which could otherwise have been quite harmful

b) Base Camp Medical Kit - Fortunately no members of the expedition suffered from any major ailment or accident, and thus no call was made upon such items as Penicillin, antimalarials etc. Several of the remaining items were used on odd occasions as the need occurred. Viso eye drops, for example, were used to give relief to one member whose eyes became very sore as the result of being in a snow storm without goggles. On another occasion, the Mycota powder was needed for the treatment of 'athletes foot'. The insect repellent cream - Mylol - was found to be unnecessary in the mountains, but it was used frequently in the tropical areas during the journey to Bolivia.

By and large, the expedition was very fortunate in keeping healthy and fit during the whole field period.

17 Expedition Conclusions W.H. Melbourne

It is now nearly six months after the expedition returned to England and it is possible to review some of its activities.

A preliminary report was put out three weeks after arrival in London and about twenty copies have been sent out in the past four months.

A far more detailed investigation of the geological structure has been made and also some thin sections of rock specimens have been studied and the results given in this report.

The map made from the plane table survey has been redrawn by cartographers of the Royal Geographical Society and is to be published in the Society's Journal.

Over two dozen known articles, with photographs, have been published about the expedition in the press of at least six countries. About five feature length articles have been published in newspapers and the Geographical Magazine is publishing four colour, and six monochrome photographs with an article. An article is also to be published in the Royal Geographical Society's Journal along with the map. Two talks have been given on the B.B.C. and one on the A.B.C., also the whole expedition appeared on Lima television.

Nine lectures have been given by the members of the expedition including a main evening lecture to the Royal Geographical Society; there are three more lectures scheduled for the immediate future.

All the firms who supplied us with food and equipment have been thanked and reports made on their products, and a lecture has been given to the staff at Aquascutum.

The Italia Line shipping company refused to make any compensation for the incredible rudeness, inconvenience, and over £150 cost which the Italian seamen's strike caused the expedition. It is most strongly advised that they are totally unreliable for an expedition to trust.

The members of the expedition have partially split to other parts of the world. Bratt has returned to Hobart, Australia to work with the Electrolitic Zinc Company. Ewart is completing his Ph.D in Mining Geology and will then be working overseas. Garrard is in his final year at the University, and hopes to take a job on the Geological Survey of East Africa. Jenkinson is now working with the Shell Company in England. Melbourne is just finishing his Ph.D. and is shortly to drive a Land Rover down Africa and up the Americas before returning to Australia. Smith is at present doing the field work for his Ph.D. in Mining Geology, north of Delhi in India, and will be returning to the Imperial College for about two more years.

18. FINANCIAL STATEMENT. W.H.Melbourne.

INCOME.

Imperial College Exploration Board Grant.	£1,000. -. -.
Mount Everest Foundation Grant.	1,350. -. -.
Personal Contributions.	300. -. -.
B.B.C. Broadcasts.	6.18. 9.
	£2,656.18. 9.

EXPENDITURE.

(a) In England.

Travel.	London to La Paz return for six.	£1,335. 7. 3.
Equipment.	Anoraks and Overtrousers.	61. 9. -.
	Boots, six pairs.	42. 6. 0.
	Duvet jackets and trousers, six.	63. -. -.
	Lilos, six.	7.16. 1.
	Sleeping bags, four. fuel cans and canvas buckets.	25.18. 2.
	Nylon rope.	5. 6. 2.
	Overboots.	6. 8. 5.
	Meade tents, three specially made.	56. 2. -.
	Rucksacks small, kit bags, primus parts, nylon cord, overgloves, pegs, sweaters, candles, hemp rope, nylon innersoles. (all greatly reduced)	30.17.10.
Freight.	London to La Paz return, equipment and food	119. 5. 8.
Film.	35mm. colour and 120 monochrome.	57.19.11.
Maps.		3.15. -.
Food.		76. 7. 5.
Insurance.	Royal Geographical Society surveying instuments and repair, and cameras	29.13. -.
Visas.		36. 1. -.
Preliminary report.		22.19. -.
Final report.		15.11. 6.
Photographic prints, map copying, map slides, and figures for reports.		18.18. 8.
Miscellaneous.	Stamps, local travel, first aid, drawing matls. lecturing exp.	20.13. 5.
Returned to Imperial College Exploration Board.		9. 8. 3.
Petty cash in hand.	(later to be returned to I.C. Exploration Board.)	20.17. 4.

Continued on next page

FINANCIAL STATEMENT CONT.

(b) Abroad.

Travel. Including air fair from La Paz to Lima for six.	189. 6. 8.
Mail and Telegrams.	15. 6. -.
Food.	104. 6. 6.
Accomadation.	115. 7. 6.
Tyres and petrol for Club Andino Boliviano truck.	95.13. -.
Bank charges.	4.11. -.
Visas.	8.19. -.
Mules and porterage.	34.18. -.
Miscellaneous, excess baggage entertaining the Club Andino Boliviano.	27. -. -.
	£2,656.18. 9.

As a reference for future expeditions it is to be noted that the travelling expences would have been about £150 less if the Italia Line had been able to fulfil it's committments. The bulk of this being caused by the air flight from La Paz to Lima, as the Italia Line failed to notify us of a change in sailing schedule.

FINAL REPORT OF THE 1959 IMPERIAL COLLEGE APOLOBAMBA EXPEDITION NOTES ON SCANNED COPY

(A.) EXHIBITS

There are 7 Exhibits included with the original report, as follows:

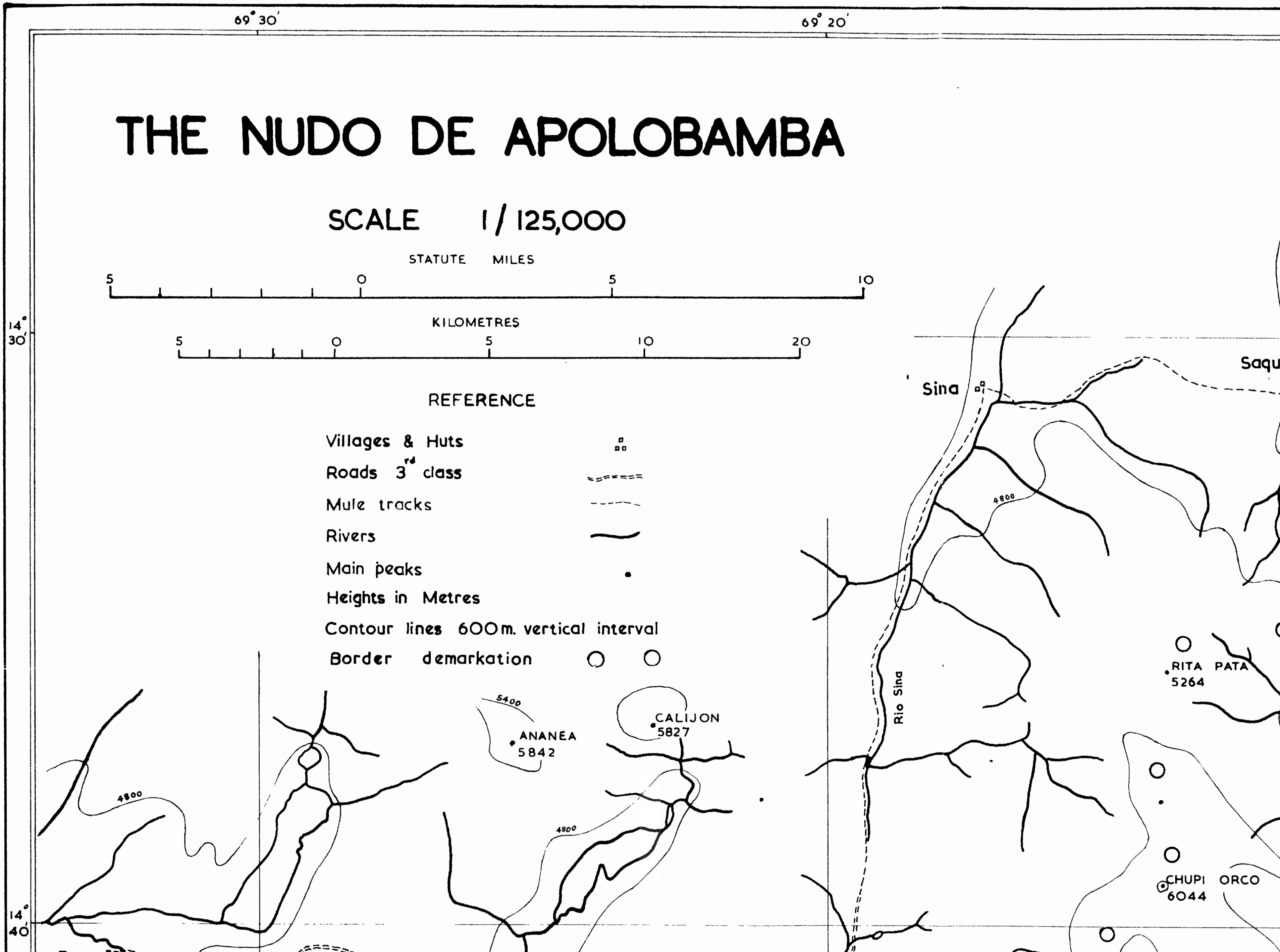
(1.) Ridge Map of the Nudo de Apolobamba (Scale 1 / 50,000).
(2.) The Nudo de Apolobamba (Scale 1 / 125,000).
Compiled from the Royal Geographical Society Peru – Bolivia Boundary Commission 1911-13 and the Imperial College Apolobamba Survey 1959.
(3.) The Nudo de Apolobamba (Scale 1 / 50,000).
Surveyed by W. H. Melbourne.
(4.) Map Showing Glaciers in the Nudo de Apolobamba Based on the Plane Table Survey by W. Melbourne.
(5.) Sections Across the Nudo de Apolobamba (Scale 1 / 50,000).
(6.) Geological Map of the Nudo de Apolobamba (Scale 1 / 100,000).
(7.) Stereographic Analysis.

Exhibit (1.) is bound into the original report after page 64 and is included in this document after page 64. Exhibits (2.) to (7.) are in a pocket inside the back cover of the original report, but they are too large for scanning and are not included in this document. Copies of the title portions of Exhibits (2.) to (7.) are included after this page for reference purposes.

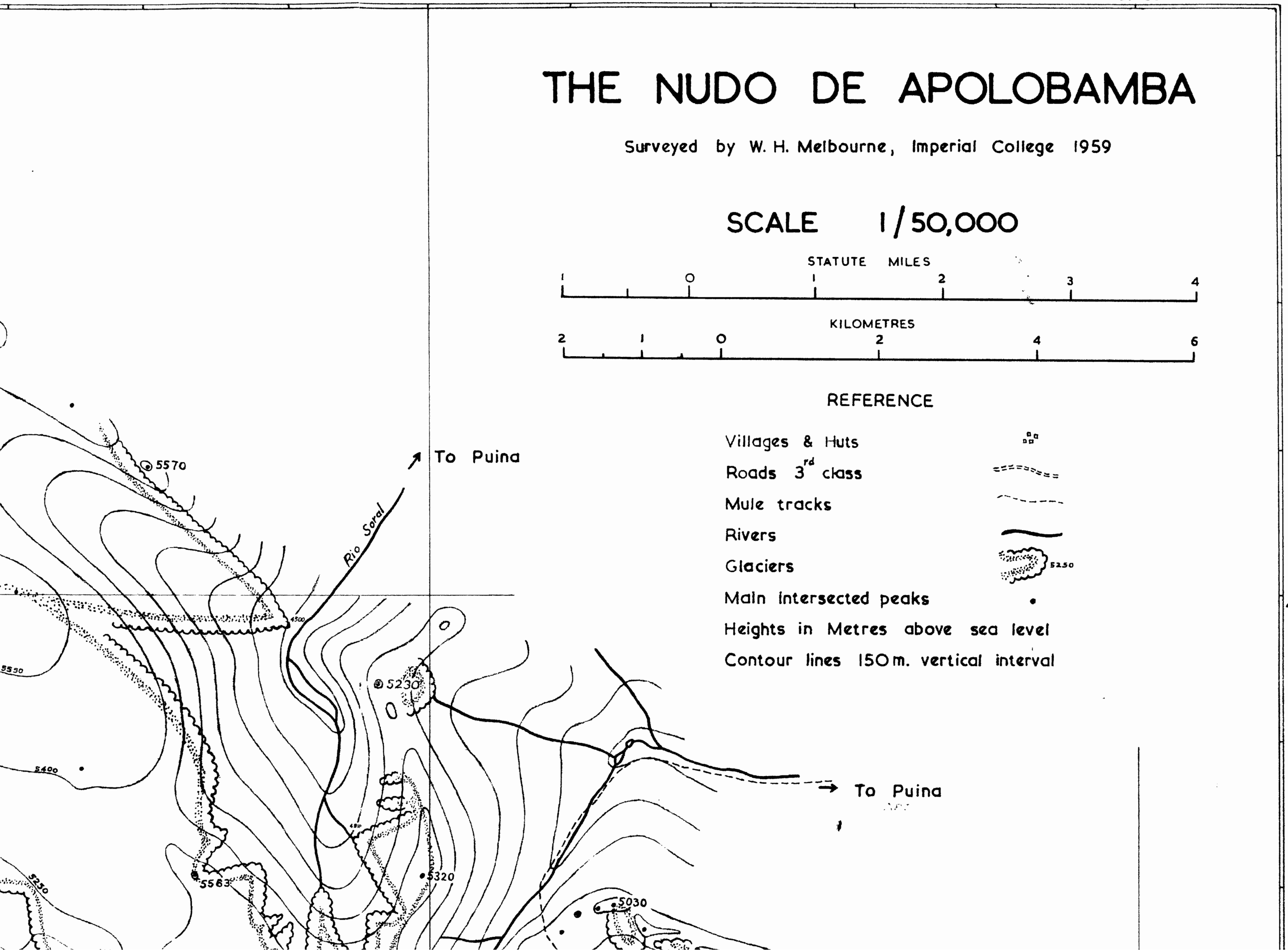
(B.) SCANNING

This document was scanned by Robert Lloyd, a member of the Imperial College Exploration Board, at the request of Nigel Wheatley, Honorary Secretary of the Board. The scanner used was a Plustek OpticBook 3600.

12 May 2009



69° 30'
69° 20'
THE NUDO DE APOLOBAMBA
SCALE 1/125,000
STATUTE MILES
5 0 5 10
KILOMETRES
5 0 5 10 20
REFERENCE
Villages & Huts
Roads 3rd class
Mule tracks
Rivers
Main peaks
Heights in Metres
Contour lines 600m. vertical interval
Border demarkation
14° 30'
14° 40'
Sina
Saqu
Rio Sina
4800
5400
ANANEA 5842
CALIJON 5827
RITA PATA 5264
CHUPI ORCO 6044

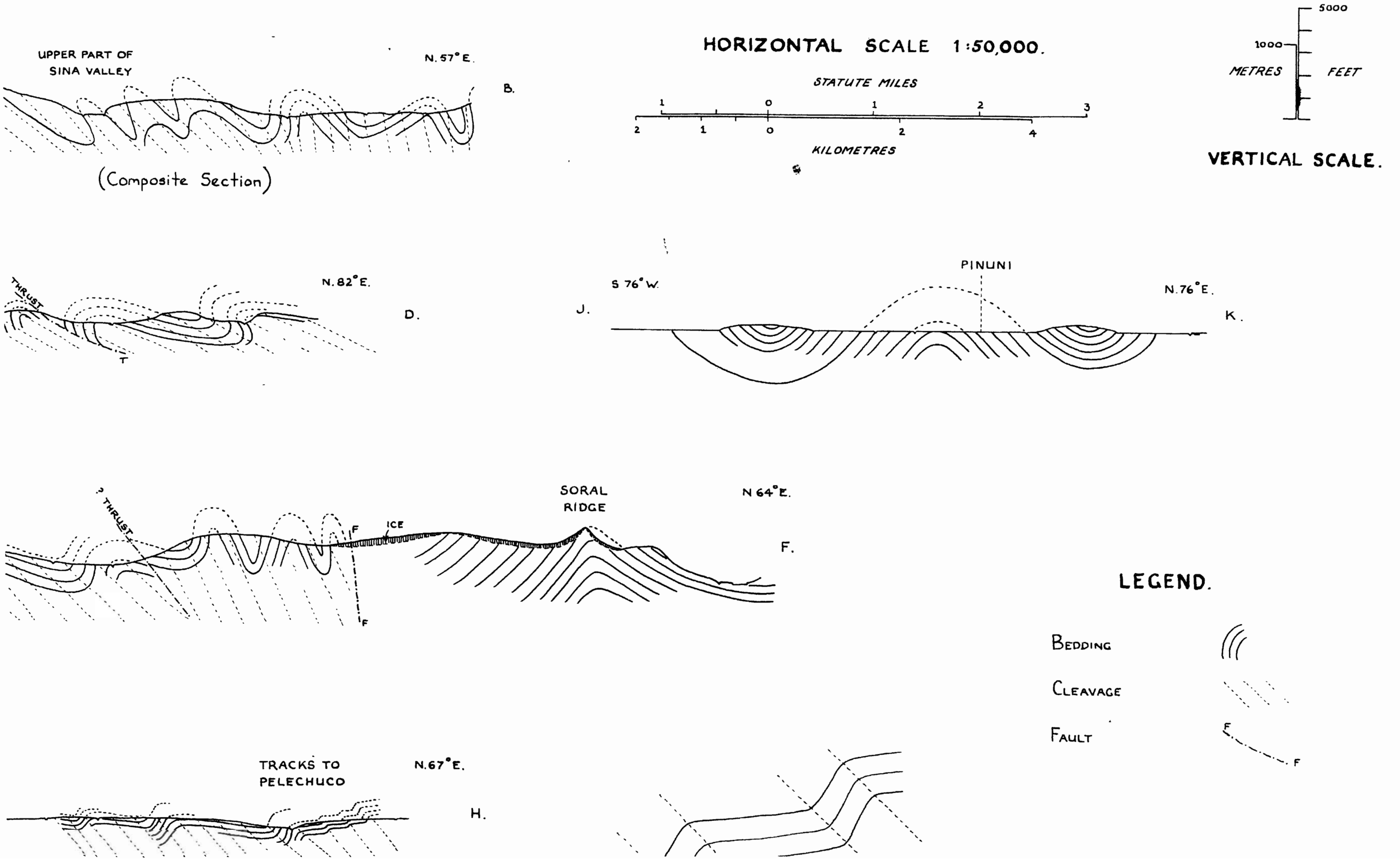

69° 10′
69° 05′
THE NUDO DE APOLOBAMBA
Surveyed by W. H. Melbourne, Imperial College 1959
SCALE 1/50,000
STATUTE MILES
1 0 1 2 3 4
KILOMETRES
2 1 0 2 4 6
REFERENCE
Villages & Huts
Roads 3rd class
Mule tracks
Rivers
Glaciers
5250
Main intersected peaks
Heights in Metres above sea level
Contour lines 150 m. vertical interval
To Puina
To Puina
Rio Saral
5570
4500
5230
5550
5400
5563
5320
5250
5030

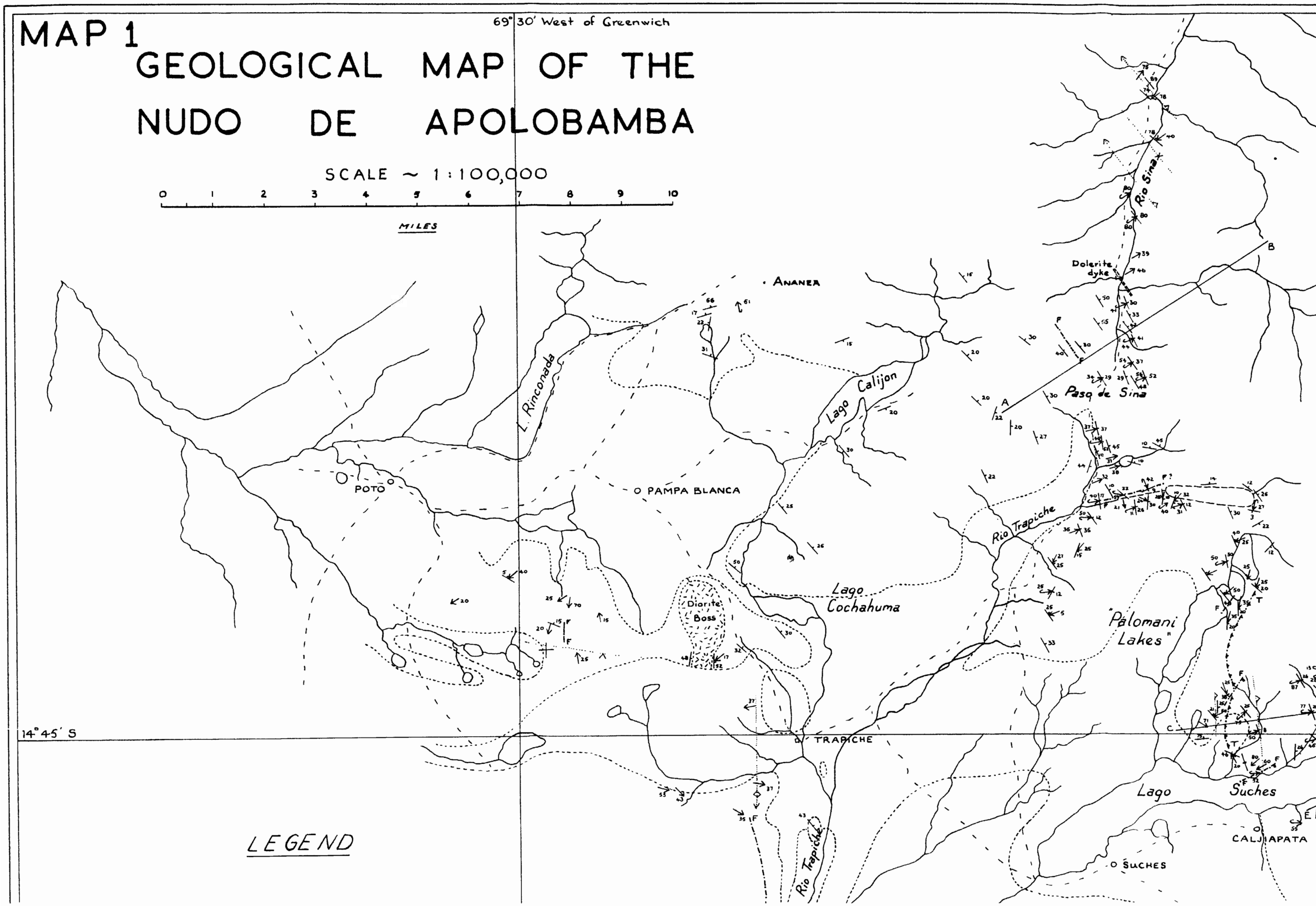
MAP SHOWING GLACIERS

IN THE NUDO DE APOLOBAMBA

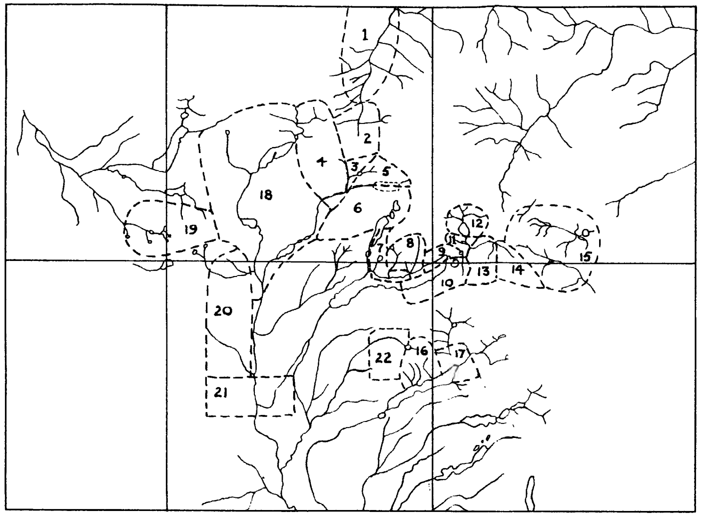
BASED ON THE PLANE TABLE SURVEY BY W. MELBOURNE

SECTIONS ACROSS THE NUDO DE APOLOBAMBA.



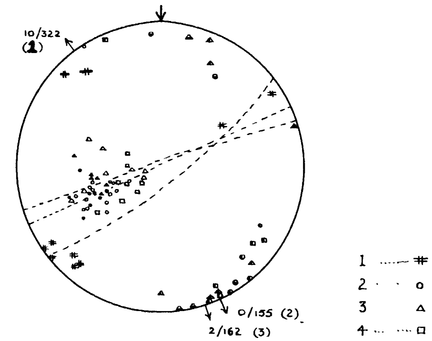

MAP 1
GEOLOGICAL MAP OF THE NUDO DE APOLOBAMBA
69°30' West of Greenwich
SCALE ~ 1:100,000
0 1 2 3 4 5 6 7 8 9 10
MILES
ANANEA
Rio Sina
Dolerite dyke
B
A
Paso de Sina
Lago Calijon
L. Rinconada
POTO
PAMPA BLANCA
Rio Trapiche
Lago Cochahuma
Diorite Boss
"Palomani Lakes"
14°45' S
TRAPICHE
C
Lago Suches
CALJIAPATA
SUCHES
Rio Trapiche
LEGEND

STEREOGRAPHIC ANALYSIS

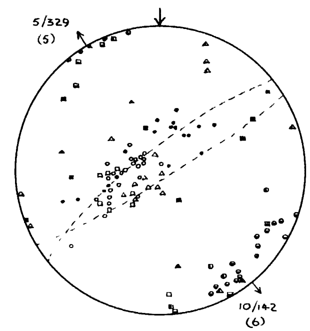


SYMBOLS USED

Poles to bedding planes	● ■ ▲ #
Poles to cleavage planes	○ □ △ #
Plunge of field-measured lineation	◐ ◧ ▲ #
Plunge of calculated lineation.	◒ ◪ ▲ #



A



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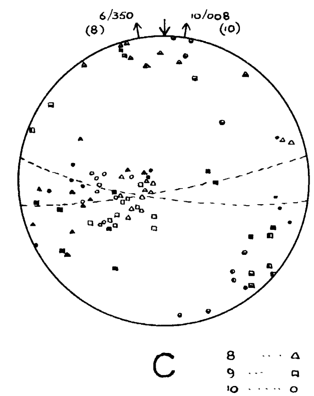

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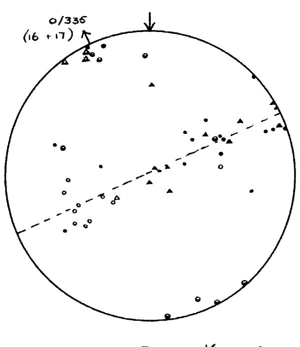

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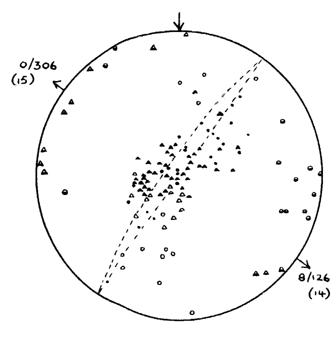

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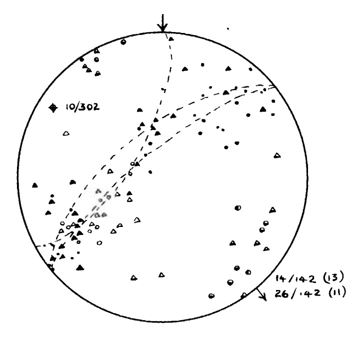

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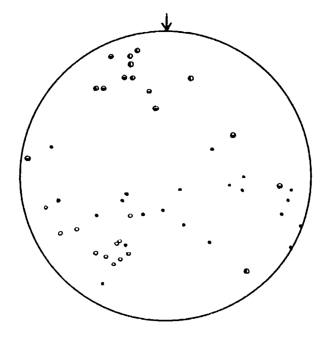

G