

SHORT NOTES

PLEISTOCENE GLACIATION IN THE ATACAMA DESERT, NORTHERN CHILE

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ABSTRACT. Morainic deposits associated with boulder spreads and outwash sands in the High Andes of the Atacama Desert are described and provide evidence of a Pleistocene glaciation. Widespread, locally folded gravel sheets of a similar age may provide a datum for correlating movements resulting in the uplift of the Andes.

RÉSUMÉ. *Glaciation pléistocène dans le désert d'Atacama, Chili du nord.* Des dépôts morainiques associés à des roches dispersées et des sables fluviatiles dans les Hautes Andes du désert d'Atacama sont décrits et témoignent en faveur d'une glaciation pléistocène. Des couches de gravier, très étendues et localement plissées, d'un âge similaire peuvent donner une date pour des mouvements corrélatifs résultant d'une montée des Andes.

ZUSAMMENFASSUNG. *Pleistozäne Vergletscherung in der Atacama-Wüste, Nord-Chile.* Es werden Moränenablagerungen im Verein mit Blockfeldern und Sandauswaschungen in den Hochanden der Atacama-Wüste beschrieben, die eine pleistozäne Vergletscherung beweisen. Weitverbreitete, lokal gefaltete Schotterdecken ähnlichen Alters mögen einen Schlüssel für die Korrelation von Bewegungsvorgängen bei der Andenhebung liefern.

DURING a study of the late Tertiary to Recent volcanoes of a region of the Andean Cordillera north of the Salar de Atacama as part of a study of the age and nature of the uplift of the Andes (Hollingworth, 1964), it was found that a number of the older, more eroded volcanic cones show glacial erosion features. Deposits of morainic character are extensive and in a number of cases well-developed valley-glacier lateral moraines are preserved.

Brüggen (1950, p. 212) described small glacial features and moraines on Volcan Toconce and also farther south, near the Salta railway. He considered that during the Pleistocene the snow line was down as far as 5,000 m., while moraines extended to 3,900 m.

To the north, in the Andes of southern Peru, Wilson and Garcia (1962, p. 47) found morainic material associated with the Pleistocene lavas at about lat. 18° S., and Tricart (1965) has described Riss and Würm glaciations at lat. 7° and 14° S.

The snow line at these latitudes is now at about 6,000 m. and Lliboutry and others (1958) have pointed out that the present glaciers in the Andes of the Atacama are found only on the three highest peaks of the Llullaillaca (lat. 24° 43' S., altitude 6,723 m.), Ojos del Salado (lat. 27° 07' S., altitude 6,885 m.) and Tortolas (lat. 29° 56' S., altitude 6,323 m.), on which there are glaciers between 6,600 and 5,323 m.

Evidence of glaciation is convincingly presented on the range of volcanoes between the Tatio geysers and Volcan Toconce (lat. 22° 10' to 22° 21' S.). Figure 1 is a sketch map of this area based on field mapping and constructed from aerial photographs. This map shows that the flanks of the Quaternary volcanoes are cut into by numerous cirque-like hollows of varying sizes. Spread in front of these hollows are deposits of glacial material. Three types of deposit are considered to be of glacial origin:

- i. Lateral moraines of the valley glaciers. These are composed of poorly sorted sands, gravels and boulders.
- ii. Hummocky spreads of angular andesitic blocks set in a sandy matrix.
- iii. Deposits of bedded sand considered to be outwash material.

The site of one of the larger valley glaciers is marked by imposing lateral moraines marked "A" on Figure 1, about 4 km. north of the Tatio geysers. At the head of the moraines is a rock step marked "C" and above this a broad U-shaped valley.

In front of the step a shallow, silted and waterlogged depression has been formed behind the large terminal moraine marked "D". Below this, lines of boulders on the inward-facing flanks and floor of the moraines mark stages of recession of the glacier, whose maximum extension beyond the rock step was about 8 km. Similar moraines are present farther north to the east of Linzor.

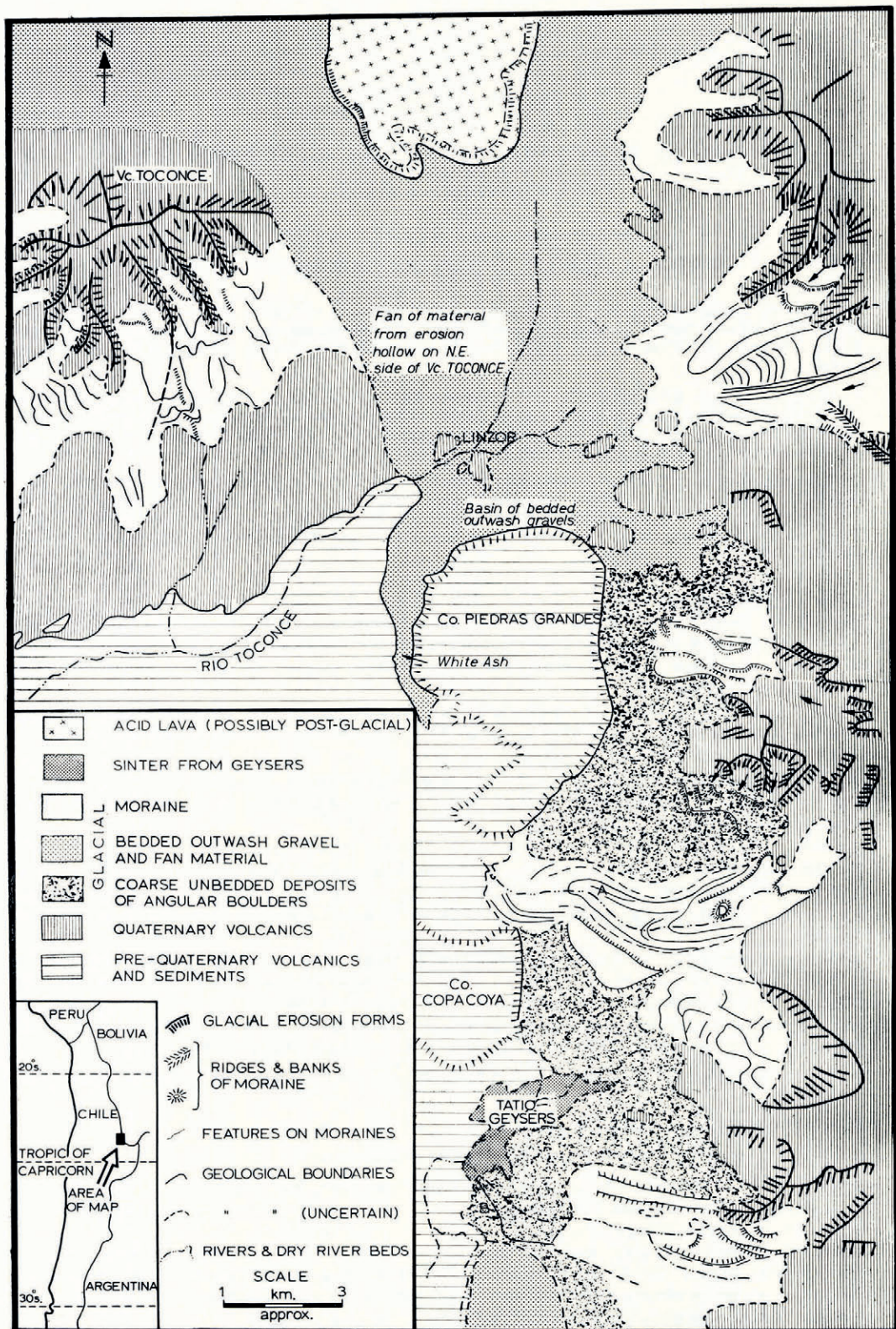


Fig. 1. Sketch map showing glacial erosion features and moraines in the area between Linzor and the Tatio geysers, Antofagasta Province, northern Chile

On the southern flank of Volcan Toconce are a number of amphitheatre-shaped hollows separated by sharp ridges or arêtes, and spreading in front of these are sheets of moraine-like material.

Between the distinctive valley-glacier moraines are the hummocky spreads of blocky material. Generally, these deposits appear to be older than the valley-glacier moraines but in some cases the distinction between them is not clear. Such deposits may well be of avalanche or mud-flow origin but their intimate association with demonstrably glacial deposits indicates that it is reasonable to consider them as belonging to the same phase of deposition. If this is true, then their much wider distribution suggests that the earlier stages of glaciation may have been more extensive than indicated by the valley-glacier moraines, and the line of boulders at "B" (Fig. 1) is considered to mark the front of one of the further extensions of the ice front to about 4,280 m.

Two basins in front of the morainic material are filled with bedded sands which are considered as outwash sands. Continued volcanic activity is indicated by beds of white ash within the sands. In the Tatio area a long north-south basin, produced in part by a late down-warp between the Alto de Cablor anticline to the west and by a line of volcanoes trending north from Volcan Tatio on the east, has been filled by these fine-bedded sands. Only part of this basin is shown at the southern end of the map (Fig. 1). The Linzor basin (shown on Figure 1) lies between the volcanoes to the east and the mass of Volcan Toconce to the west. The Cerro Piedras Grandes extrusive dome acted as a barrier to the south. One outlet from the basin was the gap now followed by the Rio Toconce.

The glacially eroded volcanic rocks are of post-ignimbrite age (the ignimbrites being of mid-Pliocene age (Rutland and others, 1965)) and are overlain by younger lava flows. The existence of a glaciation at this time may have an important bearing on sediments deposited during this same period outside the glaciated areas. To the west and south of the Tatio-Toconce area, a suite of boulder-gravel terraces extends down into the two great down-warped areas of the Rio Loa and the Salar de Atacama, and these gravel sheets have been involved in marginal up-warp and central down-warp of these basins. They are also seen to lie unconformably on the ignimbrite sheets and are overlain by lavas from the Quaternary volcanoes, indicating that their age is comparable with that of the glacial deposits. The writers therefore consider that they may well be outwash from the glacial activity at higher altitudes. The fact that in a number of places this gravel is folded with the underlying ignimbrites clearly has an important bearing on the age of the movements responsible for the uplift of the Andes. The further study of the glacial deposits and their relations with other deposits, tectonic activity and volcanism is clearly of importance in building up a complete picture of the uplift of the Andes.

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REFERENCES

- Brüggen, J. 1950. *Fundamentos de la geología de Chile*. Santiago de Chile, Instituto Geográfico Militar.
- Hollingworth, S. E. 1964. Dating the uplift of the Andes of northern Chile. *Nature*, Vol. 201, No. 4914, p. 17-20.
- Lliboutry, L., and others. 1958. Les glaciers du désert chilien, [par] L. Lliboutry, O. Gonzalez et J. Simken. *Union Géodésique et Géophysique Internationale. Association Internationale d'Hydrologie Scientifique. Assemblée générale de Toronto, 3-14 sept. 1957*. Tom. 4, p. 291-300.
- Rutland, R. W. R., and others. 1965. Isotopic ages and Andean uplift, by R. W. R. Rutland, J. E. Guest and R. L. Grasty. *Nature*, Vol. 208, No. 5011, p. 677-78.
- Tricart, J. 1965. Observations on the Quaternary firn line in Peru. *Journal of Glaciology*, Vol. 5, No. 42, p. 857-63.
- Wilson, J., and Garcia, W. 1962. Geología de los Cuadrángulos de Pachia y Palca. *Peru. Comisión Carta Geológica Nacional*, Vol. 2, No. 4.