NOMBRE	FORMULA	SISTEMA	DENSIDAD	FICHA(ASTM)
EPSOMITA	$MgSO_4 \cdot 7\ H_2O$	ORTORROMBICO	1,678	8 - 467
HEXAHIDRITA	$MgSO_4 \cdot 6\ H_2O$	MONOCLINICO	1, 76	24 - 719
PENTAHIDRITA	$MgSO_4 \cdot 5\ H_2O$	TRICLINICO	1,90	25 - 532
STARKEYITA (TETRAHIDRITA)	$MgSO_4 \cdot 4\ H_2O$	MONOCLINICO	2,01	24 - 720

Cuadro I.—**Mineralogía de los sulfatos hidratados de magnesio**

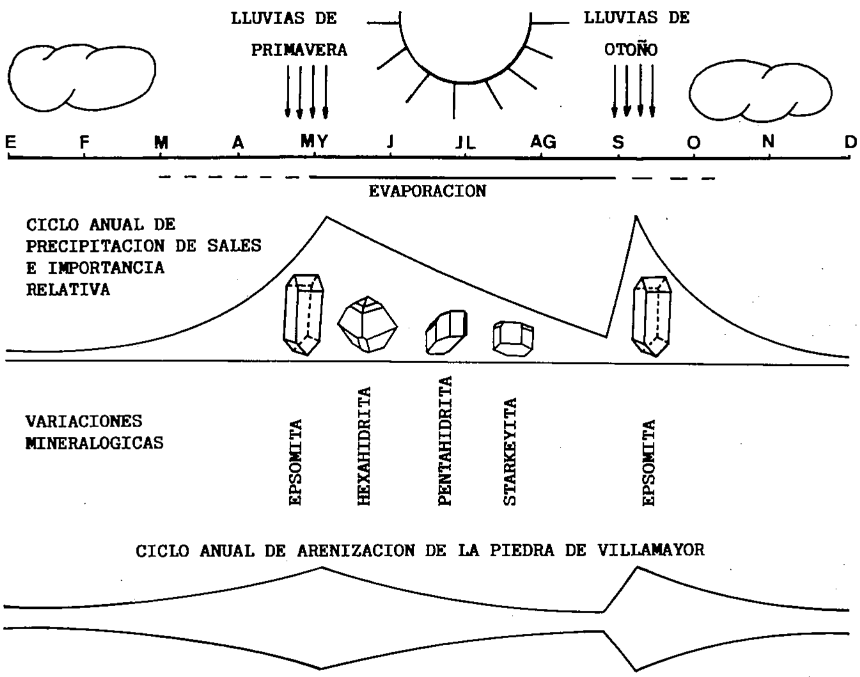


Fig. 4.—El ciclo anual de la actividad de los sulfatos de magnesio y de la arenización inducida.

Conclusión

La manifestación más evidente de la alteración ambiental de la piedra de Villamayor —piedra ornamental de los monumentos salmantinos— es la arenización. Esta se produce, principalmente, por la interacción de dos procesos diferentes. El primero de ellos es la disolución e hidrólisis selectiva de minerales del cemento como son la Clorita y las Esmectitas. El segundo es la actividad salina de los sulfatos de Magnesio con diverso grado de hidratación; esta actividad presenta un claro ciclo anual que ha sido resumido en la figura 4. El origen del Magnesio es achacable a la hidrólisis de los minerales arcillosos y el del Sulfato es presumiblemente atribuible a la contaminación ambiental.

Referencias

Alonso Gavilán, G.; Blanco, J. A.; Sánchez Macías, S.; Fernández Macarro, B. y Santisteban Navarro, J. I. (en prensa): *Studia Geol. Salmaticensia.*

Blanco, J. A.; Alonso Gavilán, G.; Fernández Macarro, B. y Sánchez Macías, S. (en prensa): *Studia geol. Salmaticensia.*

Caja de Ahorros y Monte de Piedad de Salamanca (ed.) (1984): *Serie Monografías* nº 3, 565 p.

Serrano Plaza, M. L. (1988): Tesis de Licenciatura; Univ. de Salamanca, 55 p.

Vicente, M. A. (1983): *Clay Miner.* 18, 215-217.

Vicente, M. A. and Brufau, A. (1986): *Appl. Clay Sci.*, 1, 265-272.

Recibido el 10 de febrero de 1989
Aceptado el 15 de febrero de 1989

Major Pleistocene and Holocene glacial episodes in the Khumbu region, southern side of Mount Everest (Nepalese Himalaya)

E. Martínez de Pisón (*), J. López Martínez (**).

(*) Dpto. de Geografía. Facultad de Filosofía y Letras. Universidad Autónoma de Madrid. 28049 Madrid.
(**) Dpto. de Química Agrícola, Geología y Geoquímica. Facultad de Ciencias. Universidad Autónoma de Madrid. 28049 Madrid.

RESUMEN

Se amplía hacia la vertiente meridional del Everest la cartografía de la geomorfología glaciar realizada anteriormente por los autores en el sector tibetano de este macizo. Se distinguen cuatro fases glaciares principales desde el Pleistoceno a la Pequeña Edad del Hielo, con frentes morrénicos situados a las siguientes altitudes: 2.400 m, 4.330 m, 4.600 m y 4.926 m.

Key words: *glacial geomorphology, glacial episodes, Pleistocene, Holocene, Khumbu, Everest.*

Geogaceta, 6 (1989), 35-38.

Introduction

Our geomorphological observations of the Tibetan side of Mount Everest (Martínez de Pisón, López-Martínez and Nicolás, 1986 and 1988) have been enlarged t the southern side of the range during the expedition Everest-Epson, which took place in the monsoon and post-monsoon time of 1988 (august to october).

The studied sector goes from the maximum limit reached by the glaciers in the river Dudh Koshi valley (at about 2,300 m of altitude, in the proximity of Lukla), to the top of Mount Everest, which one of us reached in the said expedition. Furthermore, some observations in confluent valleys such as Imja Khola and Ngozumpa, have been carried out. All in all we covered an area of some 800 km^2 with more than 75 km in length along the valley that leads to Mount Everest.

In addition to other geological and geomorphological observations, collection of samples and meteorological registers, we carried out a geomorphological cartography, looking specially at the distribution of the modelling and at the deposits of glacial origin. From the collected information, we propose in this preliminary note the main episodes of glaciation in the Khumbu region.

The southern side of Mount Everest

There is a clear contrast between the southern side of Mount Everest and its northern area. In Tibet the bottoms of the glacial valleys fall smoothly with an altitude never below 4,000 m; rainfall is relatively scarce and the fronts of the present glaciers reach 5,250 m in the Central Rongbuk. On the Nepalese side however, the South monsoons cause more rain to fall in that area; the valleys are deep producing considerable differences in altitude and wide heads that unfold in confluent branches, all of which caused the union of several tongues in the main collectors during the Pleistocene. The present fronts in the glaciers of the Nepalese side reach 4,900 m in the Khumbu, 5.050 m in the Imja Khola and about 4,700 m in the Ngozumpa.

Various authors have looked at several aspects of the episodes of the Pleistocene and Holocene glaciation in the southern valleys of Mount Everest. Nevertheless, they don't agree in the distribution of the existing phases. One work (Selby, 1988) considers the existence of only two main episodes. Others distinghish up to 4 episodes (Hiroji, 1981) or even more (Kuhle, 1986). The published material we have been able to see shows partial morphological cartographies with little detail in most cases. On the other hand, in the Tibetan side we have recognized four main glacial episodes older than the present one (op. cit. 1986 and 1988).

In the enclosed map (fig. 1) the distribution of the main forms and glacial deposits, as well as fluvial and slope deposits associated to them, is shown. This leads to an interpretation of the glacial fluctuations.

Main glacial episodes

The lowest glacial deposits seen in the area are located near Lukla at an altitude of 2,300-2,400 m. They consist in two wide moraine arches deeply incised by the river Dudh/Koshi. Nearby, downriver, traces of glacial erosion can be seen, stretching as far as the village of Surke (2,300 m).

The said moraines are located at about 75 km from the summit of Mount Everest, measured along the main valley. It has to be taken into account that, in addition to the incoming ice from the cirque that formed the head of the Khumbu glacier (Pumori - Everest - Lhotse - Nuptse), large tributary contributions of the Imja Khola, the Ngozumpa (Gokyo) and the Kya Shar (Thame) were very important, these last ones joining the ices of the previous glaciers at progressively lower altitudes and more to the South.

The coupling of these facts to the favourable location to get the monsoon rainfall, whithin the characteristics of the Peistocene climate of the Nepalese valleys, may explain the low and distant altitude of this glacial maximum in the Lukla valley. The side moraines existing in the proximity of Namche Bazar (fig. 1) belong also to the Lukla episode.

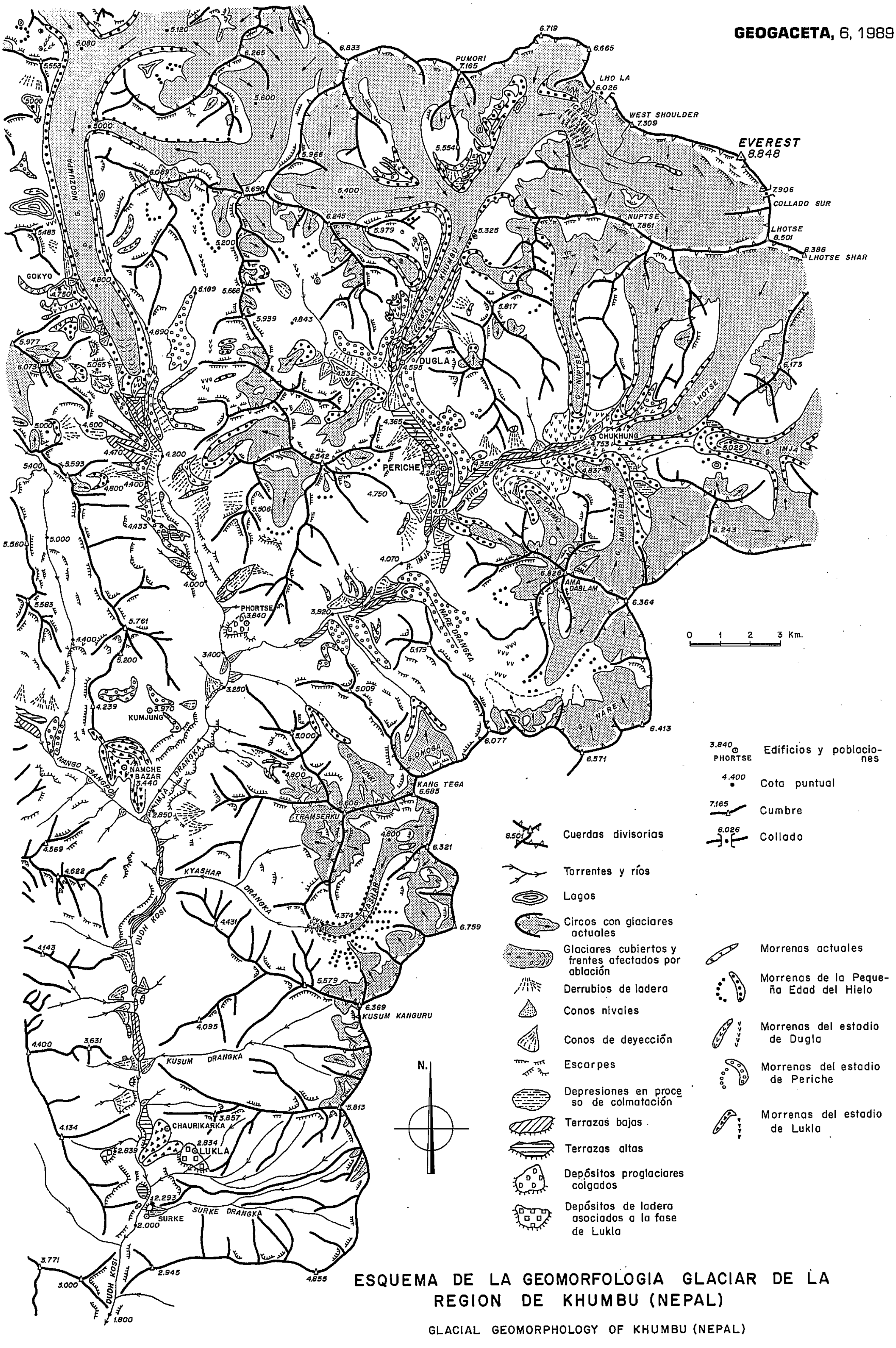
At Ghat, 4 km to the north of the Lukla moraines, we found deposits that have been considered moraines corresponding to a new episode (Hiroji, 1981). We think that they are torrential deposits coming from the side valleys.

A bigger episode is represented by the Periche moraine set. The perfect glacial trough, where the houses and fields of Periche are located, shows a moraine closure where the rests of seven well-defined arches, relatively close to each other, can be seen (fig. 2).

5 km up from the frontal arches of Periche, we found another set of mighty moraines, not far away from the present glaciers, corresponding to the phase called Dugla.

The best preserved of the recent glacial episodes is the one belonging to the «Little Ice Age» (approximately between the XVII and XIX centuries). However, it is interesting to note the loss of volume, during the XX century, undergone by the glaciers of that period, resulting in the present formation (fig. 3). We can see that the level of ice during the «Little Ice Age» appeared in some places around 50 m above the surface of the present glacier of Khumbu. This decrease in the thickness of the ice

Fig. 1.—Traducción inglesa de la leyenda, en el mismo orden en que se citan: Dividing ridges. Torrents and rivers. Lakes. Cirques with existing glaciers. Covered glaciers and fronts affected by ablation. Slope débris. Nival cones. Cones of dejection. Escarpments. Depressions undergoing colmatation. Lower terraces. Upper terraces. Hanging proglacial deposits. Slope deposits associated with the Lukla episode. Buildings and villages. Roint height. Summit. Pass. Existing moraines. Moraines of the «Little Ice Age». Moraines of Dugla episode. Moraines of Periche episode. Moraines of Lukla episode.



ESQUEMA DE LA GEOMORFOLOGIA GLACIAR DE LA REGION DE KHUMBU (NEPAL)

GLACIAL GEOMORPHOLOGY OF KHUMBU (NEPAL)

Fig. 2.—Moraine closure of the Periche episode, with its front incised, at 4,249 m, by the waters of the Lobuche Khola. In the background, the top of the Kangtega is visible (6,779 m) and at left the effects of the great flood of 1979 in the Ama Dablam moraine can be seen.

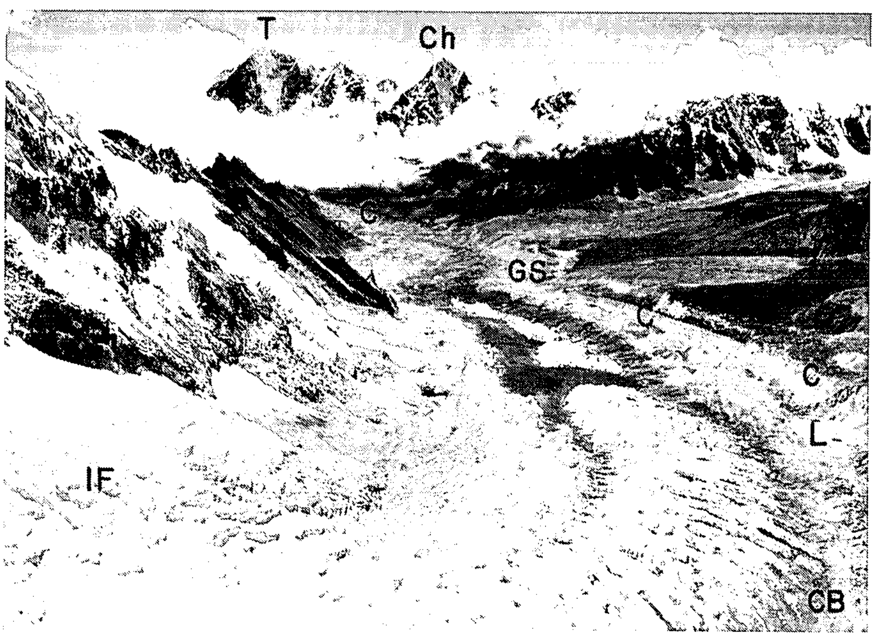


Fig. 3.—Khumbu glacier seen from the western ridge of Mount Everest. IF: Khumbu Icefall. CB: Base Camp (5,350 m). L: supraglacial lake. GS: intermoraine depression of Gorak Shep. C: moraine ridge of the «Little Ice Age». T: Taboche (6,542 m). Ch: Cholatse (6,440 m).

has caused many slides in the slope deposits bordering the tongues. In the same way it has originated the highest development and instability of the serac barriers, as is the case in the southern wall of Lho La or the Khumbu Icefall, where frequent and important slumps occur. Likewise one can see a recession of the fronts where today moraine masses of ablation appear.

Conclusion

In consequence, we can establish one episode, probably Pleistocene (Surke-Lukla), another more recent characterized by numurous pulsations (Periche) and two others, even more modern, close to each other (Dugla and the «Little Ice Age»), the last one belonging to historic times (XVII to XIX centuries). Their correlation with the stages known in the Rongbuk valley, on the northern side of Mount Everest —that we shall present in a more detailed paper—points out a parallelism in the glacial evolution in both sides of Mount Everest, despite the geographical and climatic differences of the Nepalese and Tibetan areas.

Bibliography

Hiroji, F. (1981): In *Proc. Symp. Qinghai-Xizang (Tibet) Plateau. Beijing.* 1641-1648.

Kuhle, M. (1986): In *Nepal Himalaya Geo-ecological perspectives. Delhi.* 437-473.

Martínez de Pisón, E.; López-Martínez, J. y Nicolás, P. (1986): *Geogaceta,* 1, 21-23.

Martínez de Pisón, E.; López-Martínez, J. y Nicolás, P. (1988): Observaciones geomorfológicas en la vertiente tibetana del Everest. Madrid. 159 p.

Selby, M. J. (1988): *Z. Geomorph. N.F.* Suppl. Bd. 69, 133-152.

Recibido el 10 de febrero de 1989
Aceptado el 15 de febrero de 1989