E R D K U N D E

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GLACIATION OF THE YULONGXUE SHAN, NORTHWESTERN YUNNAN PROVINCE, PEOPLE'S REPUBLIC OF CHINA*)

With 2 figures, 5 photos and 2 tables

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Zusammenfassung: Vergletscherung des Yulongxue Shan, Nordwest-Yunnan, Volksrepublik China

Im Yulongxue Shan („Jade-Drachen-Schnee-Gebirge") - bis 5596 m Höhe, bei 27 °N Breite und 100 °E Länge im Nordwesten der Provinz Yunnan gelegen - sind die südlichsten Gletscher und Dauerschneefelder Eurasiens anzutreffen. Nach allgemeinen Beschreibungen aus den 20er und 30er Jahren war das Gebirge zwischen 1948 und den 1980er Jahren für ausländische Wissenschaftler nicht zugänglich. Der vorliegende Beitrag stützt sich in der Beschreibung der gegenwärtigen Eis- und Schneebedeckung auf das Werk des chinesischen Wissenschaftlers JEN MEI-NGO und versucht einen Abriß der jungkänozoischen Vergletscherungen zu liefern. Die gegenwärtige Schneegrenze wird in Übereinstimmung mit den Berechnungen H. VON WISSMANNS bei etwa 5000 m Höhe ü. d. M. angenommen. Zwei frühere Vergletscherungen mit Reichweiten der Gletscherenden bis 3160 m bzw. 2700 m werden als Yulong- und Lijiang-Vergletscherung bezeichnet. Die jüngere davon ist ohne Zweifel mit der Jungwürm-Weichsel-Phase zu korrelieren, während die Datierung der älteren Vergletscherung ungeklärt ist.

Previous work and general geographic setting

This paper is the report of a reconnaissance study of the present day glaciers and past glaciation of the Yulongxue Shan, a mountain range in northwestern Yunnan. It was undertaken during a 10-week interdisciplinary and multi-purpose expedition, April–June 1985. However, since this involved extensive travel in this magnificent range of snow mountains, which supports the most southerly glaciers of Eurasia, observations were made on the present-day glaciers and their late Cenozoic manifestations.

The area has been referred to repeatedly by scientific travellers during the first half of this century and was the objective of a single glaciological study in the 1950s (JEN 1958). The Yulongxue Shan, 5,596 m (Jade Dragon Snow Mountains) is one of many north-south trending mountain ranges that together comprise the Hengduan, or Transverse, Mountains, and form the borderlands of southeastern Tibet (Xizang), Burma, northwestern Yunnan, and western Sichuan. Until the beginning of the twentieth century the area was little known, a vast tract of high mountain ranges and spectacular river gorges, about the size of France, and occupied by a large number of different mountain ethnic peoples.

The region became a mecca for a select group of western scientists and naturalists, including: FRANK KINGDON WARD (1937, 1960), H. HANDEL-MAZETTI (1921), JOSEPH F. ROCK (1947), ARNOLD HEIM (1933, 1936), and EDUARD IMHOF (1947, 1974). After Liberation in 1949 it was virtually closed to foreign scientists. However, the Chinese Academy of Sciences and the Kunming Institute of Botany made an extensive investigation of the Yulongxue Shan-Lijiang region in 1956/57, producing the first account in English of the glaciation of the mounatin range (JEN 1958). In addition, the syntheses on vegetational and climatic belts, and discussion of the glaciation and snowline phenomena of the Tibetan-Hengduan region by VON WISSMANN (1960, 1961), and SCHWEINFURTH's (1957) treatise on the vegetation of the Himalaya, provide an important scientific framework. SHI (1980) and MESSERLI a. IVES (1984) have contributed to the comparative geoecology of the Gongga Shan (7,556 m) and Yulongxue Shan.

The Hengduan Mountains extend between latitudes 25° and 32° North and are bisected by the 100° East meridian, with many individual summits exceeding 5,000 m a. s. l., culminating in the Gongga Shan (Minya Konka) group at 7,556 m. The regional topography is strongly influenced by pronounced north-south tectonic alignment and is highly active seismically today. It is dissected on a gigantic scale by the upper reaches of the Irrawady (Nmai Jiang), the Salween (Nu Jiang), the Mekong (Xiao Zhong Jiang), and the Yangtze (Jinsha Jiang) and its tributaries. These rivers plunge off the Tibetan Plateau to flow southward in closely-spaced parallel trenches often more than 3,000 m deep.

The Yulongxue Shan forms the southern culmination of the Hengduan Mountains. Further south, to about latitude 25° North, summits do not exceed

*) This paper has been prepared on the occasion of Professor Dr. WILHELM LAUER's 70th birthday. It is intended as a small token of respect to his lifelong example and leadership in mountain scholarship.

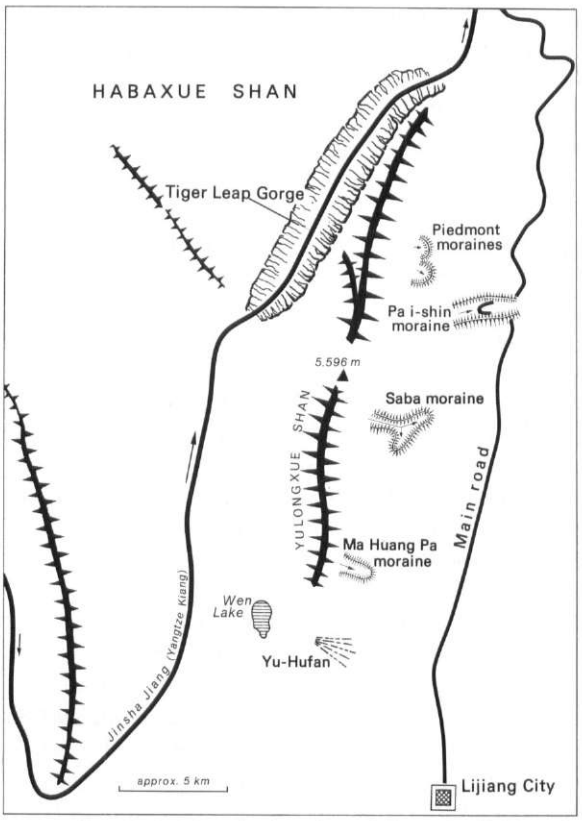

Fig. 1: Sketch showing the location of the main field study reference points. Scale and geographic positions are very imprecise because no topographical maps or air photographs were available

Lageskizze der Hauptuntersuchungsgebiete. Maßstab und geographische Lage sind sehr ungenau, da keine topographischen Karten oder Luftaufnahmen verfügbar waren

about 4,200 m and carry no permanent snow. The Yulongxue Shan, in latitude 27° North, trends approximately north-south for about 35 km along the western edge of the great loop of the Jinsha Jiang (Fig. 1). A much lower forested spur extends southward sloping down to the Lijiang Plain opposite the city of Lijiang that has served as the center of the Naxi nation for at least a thousand years.

The Lijiang Plain extends northward from the city to the east of the fault scarp of the imposing east face of Yulongxue Shan; it rises gradually in elevation from 2,475 m to about 2,800 m, with an extension further north in the form of small intermittent basins (graben). The fault-controlled eastern margin of the Lijiang Plain rises steeply to only modest heights of 2,800 to 3,400 m.

The Jinsha makes its great northern turn in latitude 26°50 North, southwest of Lijiang. It cuts between the Yulongxue Shan and the Habaxue Shan (5,396 m), also glacierized, forming a gorge more than 3,500 m deep. The narrowest part is the famous Tiger-Leap Gorge (Xia-gian-tou) which is barely 30 m across. Fig. 1 shows the general location of the field area; Fig. 2 is a sketch of the bedrock geology derived in part from JEN (1958, Fig. 1), and from unpublished sources by ZHANG.

The Yulongxue Shan is a complexly folded and faulted massif with 15 or more summits exceeding 5,000 m. Its folding axis pitches to the south so that progressively younger strata are exposed in this direction. The northern and higher part of the range is formed largely by limestones of Carboniferous and Devonian age which are pure, massive, and metamorphosed to varying degrees. The lower, southern spur is underlain by Permian basalts, Triassic limestones and shales. The Lijiang Plain has the appearance of a large graben. Its southern two-thirds is floored with alluvium. From Lijiang city, however, the surface slopes northward with a gently increasing gradient and the alluvium grades into glacio-fluvial

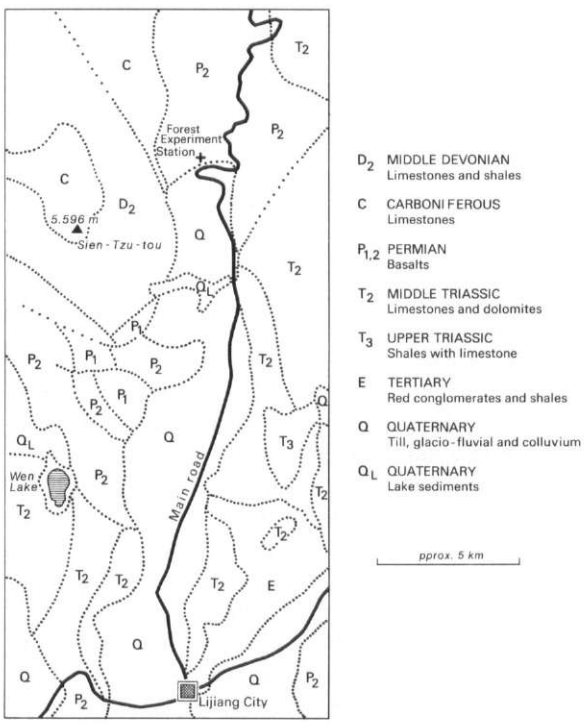

Fig. 2: Sketch of the bedrock geology derived in part from JEN (1958) and from numerous unpublished Chinese sources, compiled by ZHANG YONGZU

Skizze des geologischen Untergrundes (z. T. nach JEN (1958) sowie aus zahlreichen unveröffentlichten chinesischen Quellen, zusammengestellt von ZHANG YONGZU)

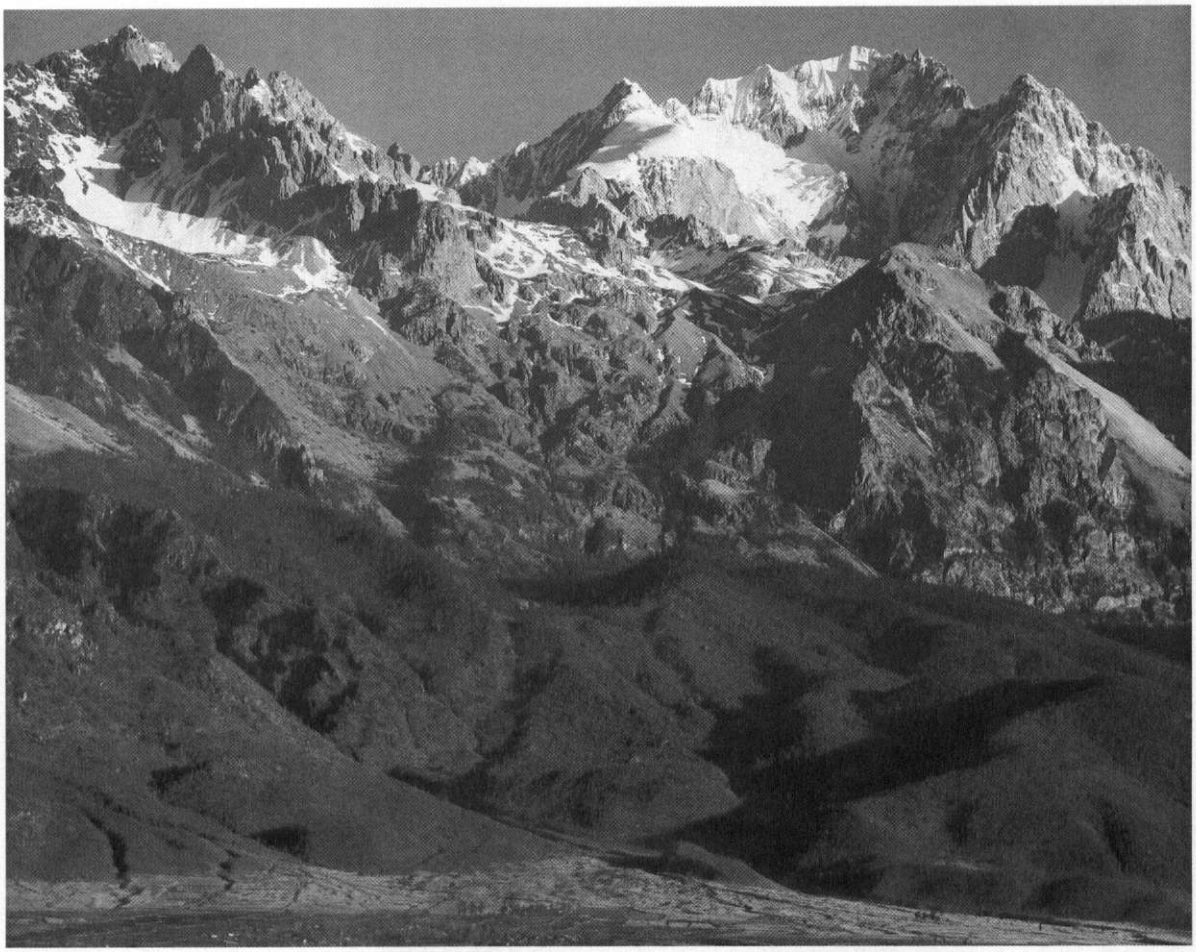

Photo 1: View of a section of the east-face of the Yulongxue Shan from the southeast. The snow peak on the right skyline is the highest summit, Sien-Tzu-tou (5,596 m), believed to be unclimbed. The cirque glacier below this summit avalanches into the deep glacial trough from which the Saba Moraines debouch. During the last glaciation, glaciers descended the east slope and deposited terminal moraines in the wooded hills of the middle ground. The distinct cirque end moraines below the left skyline peak are Late Glacial in age. The Yu-Hu-fan with JEN's "Lichiang-moraines" occupies the middle foreground

Teilansicht der Yulongxue-Ostabdachung, aus Südosten gesehen. Rechts am Horizont der höchste Gipfel (Sien-Tzu-tou, 5596 m). Der Kargletscher unterhalb dieses Gipfels fällt in ein tiefes glaziales Trogtal ab, aus dem die Saba-Moränen hervorgehen. Während der letzten Vergletscherung reichten die Gletscher an der Ostseite bis zu den waldbestandenen Hügeln im Mittelgrund herab, wo sie Endmoränen ablagerten. Die deutlichen Endmoränen im Kar unterhalb des Gipfels am linken Horizont haben spätglaziales Alter. Der Yu-Hu-Schwemmfächer mit JENS „Lichiang-Moränen" nimmt den linken Vordergrund ein

outwash. A cluster of complex low rounded hills cuts off the northern end of the plain. They extend up to 5 km eastward of the scarp face of Yulongxue Shan and also contain a series of large end moraines which will be described below. Further north the smaller graben are also partially floored by alluvium, and by glacio-fluvial deposits.

The entire Hengduan region is assumed to have been strongly folded and uplifted during the Mesozoic orogeny (JEN 1958). Subsequent denudation, according to JEN, reduced it to form the Yunnan Peneplain. Regardless of this specific interpretation, there are extensive remnants of a dissected surface at about 3,000 m apparent in the present landscape. The upland surface is conjectured to have been uplifted again, block-faulted and tilted, in the late Tertiary. The resulting present-day landscape is characterized by major north-south alignments and east-west

Photo 2: View onto the east face of the Yulongxue Shan from the northeast, emphasizing the dominance of the major fault scarp. The Saba Gorge of JEN (1958) cuts into the east face near the extreme left skyline; the Pa i-shin Gorge crosses the extreme right middle ground. The basins in the middle ground are graben. Immature glacial landforms, particularly conspicuous to the right, dissect the limestone face

Blick auf die Ostabdachung des Yulongxue Shan aus Nordosten mit augenfälliger Hauptbruchstufe. Die Saba-Schlucht nach JEN (1958) ist nahe dem Horizont links in die Ostflanke eingeschnitten; die Pa i-shin-Schlucht zieht sich durch den äußersten rechten Mittelgrund. Die Becken im Mittelgrund weisen Grabenstruktur auf. Unausgereifte Glazialformen gliedern den Kalk-Steilabfall (besonders deutlich an der rechten Seite erkennbar)

cross faulting. Tectonic movements have continued throughout the Pliocene and Pleistocene to the present so that the main topographic lineaments are tectonic in origin.

Present glacierization of the east face of Yulongxue Shan

In contrast to the remoteness of the western slope, the east face of Yulongxue Shan is relatively accessible. It is especially easy to obtain extensive photographic panoramas from a line of hill summits that rise to between 2,800 and 3,400 m some 8 to 15 km eastward of the main range. Views from the southeast (Photo 1) and northeast (Photo 2) emphasize the fault-scarp controlled nature of this massive east-facing limestone wall. Photo 2 shows the northerly summit (5,300 m). The higher slopes of the range (i.e., above timberline which lies at about 4,000 m) are generally much too precipitous for the accumulation of significant volumes of ice and snow. The northern summit ridge, however, was reported to carry a small ice cap (Rock 1947).

Further south the northeastern slopes of the main summit (Sien-Tzu-tou, 5,596 m) are more broken and support one of the range's largest cirque glaciers (Photo 3). Characteristically, the cirque form is immaturely developed and the glacier more nearly has the appearance of a short hanging valley glacier. It appears to have thinned and retreated very slightly since the 1920s when it was photographed by Rock (1947). The snout descends to about 4,100 m.

The view onto the southeast face of Sien-Tzu-tou (Photo 1) reveals a somewhat more advanced stage of glacial (cirque) erosion, especially below the main summit itself with its avalanching, ice-fretted ridges. The pronounced cirque beneath the dark rock summit on the left skyline of Photo 1, however, does not contain any permanent ice. Moreover, the conspicuous cirque-lip moraines, from this distance originally suspected of being Neoglacial in age, were subsequently determined to be of Late-Glacial age. The slopes below 4,000 m, displaying a very irregular upper timberline, are festooned with lateral and end moraines that descend into the low wooded hills of the middle ground. They are discussed in more detail below.

Jen (1958) concluded that the local snowline in the main east-facing cirques must lie between 4,400 and 4,500 m while the climatic snowline for Yulongxue Shan as a whole is much higher, at about 5,000 m. Shi Ya-feng (1980), in his general treatment of the glaciers of China, assumes a climatic snowline of between 4,600 and 4,800 m, although this is probably too low. Von Wissmann (1959), depending only on the accounts of the early travellors and explorers, assumed an altitude of 5,100 m for the climatic snowline.

The great glacial anomaly of the east face of the range is a spectacular hanging glacier which reconstitutes itself twice by avalanching over steep cliffs. It was reported to end in an ice-avalanching glacier at 3,625 m. Inspection of the magnificent Neoglacial moraines of this glacier revealed a rock glacier inside the moraines partially covered with ice-avalanched debris in April (1985) which almost certainly would melt completely during the summer ablation season. It is proposed, therefore, that the earlier descriptions result from a misinterpretation. An actual glacier terminus at approximately 3,600 m on inaccessibly steep cliffs, confirms Jen's (1958) observation (Photos 4 a. 5).

The difficulty of more accurately establishing equilibrium line altitudes and climatic snowline is in part related to the lack of data from the upper levels of Yulongxue Shan, the pronounced seasonal monsoon nature of the climate, and the corresponding problem of summer observations when the transient snowline is believed to be lower than in winter and spring (Jen 1958). During the summer monsoon the mountain range is enveloped in cloud for long periods. Table 1 gives the standard climatic means for Lijiang, situated at 2,450 m and about 15 km south of the main summit. Von Wissmann (1959) has made some highly interesting and ingeneously argued conclusions concerning the regional trends in altitude of the main vegetation belts and climatic snowline, and these have not been superseded. During May–September, 1985,

Table 1: Climatic data for Lijiang, altitude 2,450 m (1955–1978)
Klimadaten für Lijiang, Meereshöhe 2450 m (1955–1978)

Monthly precipitation (mm)					Mean monthly air temperature (°C)				
Jan.	July	Sept.	Dec.	Year	Jan.	July	Sept.	Dec.	Year
1.9	259.1	133.0	2.2	953.0	5.8	17.9	15.9	6.3	12.6

Photo 3: Cirque glacier under the east face of Sien-Tzu-tou, 5,596 m, Yulongxue Shan. There is very little change in the volume of ice since it was photographed by Joseph F. Rock in the 1920s

Kargletscher unterhalb der Ostabdachung des Sien-Tzu-tou (5596 m, Yulongxue Shan). Das Eisvolumen hat sich seit der photographischen Aufnahme von J. F. Rock in den 20er Jahren nur wenig verändert

a series of 12 rain gauges were maintained between 2,500 and 3,200 m on the eastern rim of the Lijiang Plain opposite the southern end of the range (observations made by members of the 1985 reconnaissance expedition – not published). A provisional analysis of the precipitation data collected reveals a summer monsoon precipitation gradient of 30 mm/100 m. This fits well with von Wissmann's extrapolations. However, too much reliance cannot be placed upon an extrapolation of the 1985 precipitation and temperature gradients to altitudes above 3,500 m. Such a technique, nevertheless, indicates that the 5,000 m estimate for the altitude of the climatic snowline is a reasonable first approximation (cf. Messerli a. Ives 1984). It is regrettable that not even comparable data is available for the western slope. The occurrence of small summit ice caps on neighbouring Habaxue Shan at 5,200 m (Rock 1947) is the only additional information.

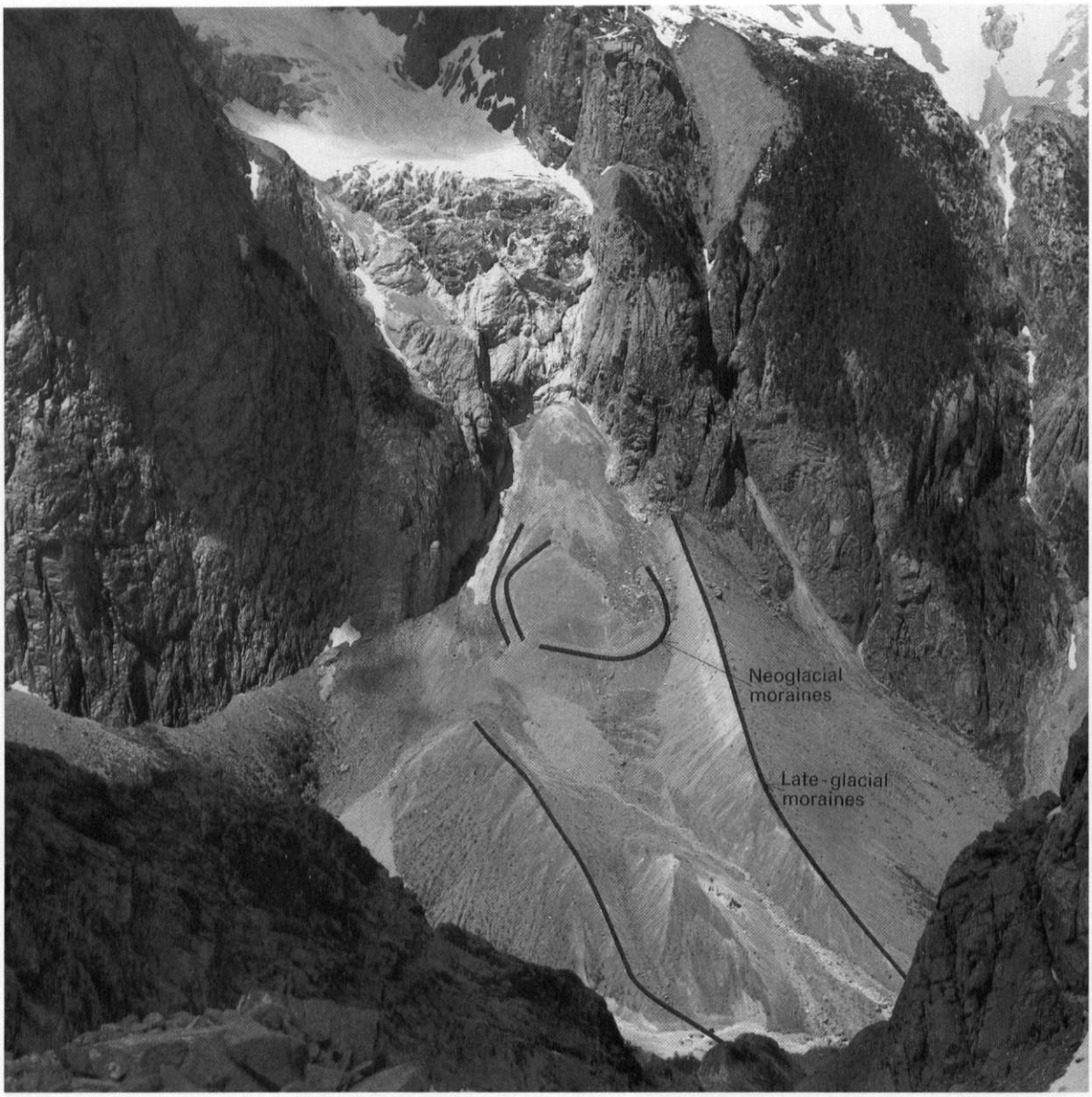

Photo 4: Late-glacial and Neoglacial (inner) moraines from hanging and avalanching glacier beneath Sien-Tzu-tou, 5,596 m, Saba Gorge

Spätglaziale und neoglaziale (innen gelegene) Moränen des hängenden und in Eisbrüchen abstürzenden Gletschers unterhalb des Sien-Tzu-tou (5596 m), Saba-Schlucht

Pleistocene glaciation of Yulongxue Shan

JEN, from his fieldwork in 1957, concluded that the Yulongxue Shan had been influenced by much more extensive glacierization than today on at least two occasions in the past. These he named the "Tali (Dali)" and "Lichiang (Lijiang)" glaciations, the latter being the older and more extensive.

The type area for JEN's "Lijiang Glaciation" is just south of the village of Yu-Hu where there are "seven low hillocks arranged in a crescent plan with its convex side facing east" (JEN 1958, p. 312). This he describes as the A-li-Li-Chu terminal moraine; the hillocks lie along the distal edge of a large alluvial fan emanating from the break between the main range of the Yulongxue Shan and the lower southern spur that

Photo 5: Low altitude view from within Saba Gorge showing the Late-glacial and Neoglacial moraines of the avalanching glacier (compare Photo 4)

Blick aus geringer Höhe innerhalb der Saba-Schlucht auf die spätglazialen Moränen des abstürzenden Gletschers (vgl. Photo 4)

is underlain by Permian basalts and Triassic limestones and shales. This critical locality was visited and carefully examined by the authors. While JEN's general description is verified, his interpretation that the seven mounds constitute the remnants of a terminal moraine is not accepted.

The Yu-Hu fan is the northerlymost of a series of alluvial fans, that partially coalescing, form the western margin of the Lijiang Plain. Their apexes lie at the mouths of a series of fluvial gorges cut into the eastern slope of the low southern extension of the Yulongxue Shan. JEN's (1958) seven mounds form a low arc at the extreme distal edge of the fan at an altitude of about 2,700 m a. s. l. They rise between 2 and 3 meters above the general surface; the largest has a surface area of about 80 by 16 meters. Their

composition is principally limestone rubble ranging from large blocks to gravels and sands. There is a scattering of basaltic cobbles on the surface of the mounds, although shallow trenches dug to 1 m depth revealed only limestone material. The fan itself is liberally littered with basaltic pebbles and cobbles and occasional boulders up to one meter diameter. Fluvial gulleys cut in the fan surface reveal that basaltic debris are entrained within the fan stratification. The mounds are partially buried by the alluvial deposits.

The morainic nature of the mounds could not be unequivocally demonstrated. They could be the dissected remnants of a debris flow, or former higher fan surface; clast shape is predominantly rounded to sub-rounded. The most serious argument against a glacial interpretation is that the mountain ridge to their west, from which any such glacier would originate, is of very modest altitude. Inspection of the lower slopes revealed no evidence of former glaciation and the low altitude prompts the inference that the potential source area would lie below any palaeo-snowline. On this basis the support for the "Lijiang Glaciation" is discounted, although no definitive alternate interpretation of the low hillocks has been formulated.

JEN's (1958, p. 312) evidence for a Dali Glaciation is much more convincing, and includes some of the most spectacular end and lateral moraines the authors have ever seen. The generally unbroken limestone wall of the Yulongxue Shan east face (Photo 2) is partially breached in two localities by deep U-shaped gorges believed to be the result of erosion along two major sets of cross-faults. Neither east-west trending gorge has cut through to the main summit ridge although together they have produced some of the most dramatic scenery on the entire eastern side of the range. The southern gorge penetrates to beneath the main peak of Sien-Tzu-tou where it ends in a gigantic rock wall. The avalanching glacier with its high Neoglacial moraines falls over the north wall of the gorge onto its floor at 3,600 m. The main valley is a classic U-shaped gorge with precipitous rock walls rising over 2,000 meters. The former glacier debouched from the gorge and almost penetrated through the low hills (forested today) onto the upper Lijiang Plain. Its outer limits are marked by a well preserved set of end and lateral moraines. The gorge was named So-Pa (Saba) by JEN (1958) and this name is extended to the moraines. They form an impressive bifurcating loop presumeably the result of low limestone bedrock hills causing the original glacier terminus to divide into northern and southern lobes. The floor of the northern lobe is a broad level expanse underlain by a highly carbonaceous loam, presumeably a silted former moraine-dammed lake. This broad valley is named Kan-Hoi-Pa on JEN's block diagram (1958, Fig. 4, p. 310). It was described and photographed in 1925 by ROCK and the morainic characteristics were first noted by him. The floor of this dry valley lies at about 3,160 m. The end and lateral moraines rise 90 m above it and have a distal height varying between 195 and 230 m, although the height of the frontal edge is exaggerated by the limestone bedrock hills that are thinly plastered with till and large erratic blocks.

Six kilometers south of the Saba moraines lies another end-lateral moraine complex, less prominent and more nearly concealed by the low frontal bedrock hills. The broad valley floor within the end moraine loop is named Ma-Huang Pa by JEN and has been used for generations by Naxi farmers as a grazing and camping place, and a base for logging operations. Its altitude is about 3,276 m and, as concluded by JEN, the end moraines were most likely formed contemporaneously with the Saba moraines by a large glacier that descended the steep eastern flanks of this southern section of the main Yulongxue Shan range, being supplied by ice discharging from a group of cirques with thresholds between 4,000 and 4,200 m. The slopes above the Ma-Huang Pa end moraines, as mentioned above, are festooned with lateral morainic arcs displaying a complex of maximum and retreat phases that finally terminated in separate cirque moraines at and close to the level of the cirque thresholds. As mentioned earlier, these cirque moraines, when first seen from a distance, were initially thought to be of Neoglacial age (Photo 1). Inspection on the ground, however, revealed a well-developed alpine soil with strong vegetation cover in favorable localities and a mature covering of crustose lichens on the larger blocks. Despite the existence of these well developed cirques and the assumed proximity of the local snowline, no evidence of Neoglacial glaciers was found.

The second major U-shaped gorge that cuts deeply into the eastern face of the Yulongxue Shan lies about 10 km north of the Saba Gorge. It was also described and photographed by JOSEPH ROCK (1947) but is not mentioned by JEN, lying immediately beyond the right-hand (northern) limit of his block diagram (JEN 1958, Fig. 4). The present logging road, following the route of an ancient trail, descends obliquely into the lower and outer section of this gorge after crossing the northerlymost of the small graben. The road descends to one of the few surface streams (Pa i-shin) of the area and it is proposed to extend this name to the gorge

also. The road then completes a broad loop by swinging eastward and ascending the northern slope of the lower gorge, providing access to a forest research station (Photo 2).

The upper Pa i-shin Gorge is a fault-controlled glacial trough with precipitous slopes giving onto the northerly approaches to Sien Tzu-tou, although it does not have the beautiful symmetry of the Saba Gorge. It was obviously over-deepened by a former valley glacier, or outlet glacier, which then proceeded to cut through the low, presently wooded, bedrock hills at the base of the range. This lower gorge is thus a much more gentle U-shaped trough with a vertical relief of about 180 m (Photo 2). The glaciated form extends for about 6 km eastward of the road bridge beyond which it becomes a steep and chaotic fluvial ravine. The southern lip of the lower gorge is at first topped by a pronounced lateral moraine. After about 2 km, however, the lateral moraine descends obliquely at a slight angle into the gorge itself. The northern side of the lower gorge has a similar feature, although not so well-developed, or preserved. The two lateral moraines approach one another where the character of the gorge changes from a regular broad U-shape to a chaotic fluvial ravine, so that no conspicuous end moraine could be determined amongst the densely-forested steep slopes. Nevertheless, the form of the lower gorge with its marked lateral moraines indicate that a glacier, fed from the upper slopes of the Yulongxue Shan, must have extended at least 6 km from the base of the range and terminated below 2,700 m. This would make it the largest Pleistocene glacier on the eastern side of the range. The coincidence of the lateral moraines with the glaciated form of the lower gorge would also indicate that any earlier glaciation did not produce a significantly more extensive ice cover in this vicinity.

North of the Pa i-shin Gorge the east face of Yulongxue Shan is scalloped by a series of shallow glacial troughs indicating the former existence of steep cascading valley glaciers. These descended and partially coalesced within the low bedrock hills, as evidenced by a complex of lateral and terminal moraines and irregular mounds of ablation till. There is evidence for the former existence of a small piedmont lobe extending about 1 km out from the base of the great limestone wall and descending to about 2,900 m.

It is presumed that the Ma-Huang Pa (JEN 1958), the Saba, the Pa i-shin, and the northerly piedmont moraines were formed contemporaneously. It is also presumed that they mark the outermost limits of the last major glaciation of the Yulongxue Shan (late Würm equivalent). This conclusion is supported by the comparable degree of soil development, vegetation cover, slight induration of the till, and especially the compatible topographic locations and distinct, undissected morainic form. JEN (1958) assigned the Ma-Huang Pa and Saba moraines to his Tali (Dali) Glaciation, which he also interpreted as "last glacial maximum".

The name Tali (Dali) was derived from a series of cirque moraines at about 4,000 m in the mountain range west of the city of Tali (Dali), the capital of the Bai nation about 250 km south of Yulongxue Shan. While it was not possible for the authors to visit these cirque moraines, which JEN describes as the most southerly evidence of Pleistocene ice in Yunnan, from his account it appears that they are indistinct as well as relatively inaccessible forms. In contrast, the lateral and end moraine systems along the eastern foot of the Yulongxue Shan are readily accessible and the Saba Moraines, in particular, provide a classic text book form. It is proposed, therefore, to substitute the name "Yulong Glaciation" for "Tali (Dali) Glaciation" and assign it, provisionally, a late-Pleistocene (= late Würm/Wisconsin/Weichselian) age. JEN's original terminology is deemed inappropriate, partly because of the admittedly indistinct nature of the field evidence, and partly because of their great distance from the very distinct, accessible, and unambiguously diagnostic characteristics of the Yulongxue Shan localities.

As indicated above, the Saba Moraines outline the dimensions of an outlet glacier that almost pushed through the low bedrock hills fronting the eastern face of the Yulongxue Shan (indeed, the northern lateral moraine directly overlooks the Kan-Hai-Tzu (graben), the floor of which lies at about 2,968 m). Meltwaters from glaciers of the Yulong Glaciation distributed the gravels and sands that form the northern sandur or outwash plain section of the Lijiang Plain. Similar, but less extensive glacio-fluvial deposits form the surface of the western sections of the small northern plains (graben). However, extensive till deposits were located outside the Yulong Glaciation moraines in a wide arc along the foot of the range from the north end of the Lijiang Plain into the irregular hill country north of the Pa i-shin Gorge. At their greatest extent they occur up to 1.5 km beyond the Yulong Glaciation end moraines, although no distinct outer limit was apparent and no morainic forms were discovered.

This pre-Yulong Glaciation till is comparable in texture and composition to the till of the Yulong Glaciation. It is a coarse bouldery till with clasts up to

Table 2: Chronology and terminology for the glaciation of the Yulongxue Shan
Chronologie und Terminologie zur Vergletscherung des Yulongxue Shan

Glacial stage/phase	Equivalents	Extrapolated age BP
Neoglacial	Neoglaciation (several)	3,000–100
Yulong Glaciation	Late-Würm/Wisconsin/Weichselian	25,000–18,000
Lijiang Glaciation	Early-Würm? or pre-Würm?	?–?

3 m diameter and is composed predominantly of limestone, marble, and limestone conglomerate, with occasional blocks of basalt and shale. Limestone clasts are occasionally striated. However, it is much more firmly indurated and limestone blocks could only be extracted from the till matrix with extreme difficulty, even in well-exposed road cuts. Many kilometers of road-cut are available for examination, but repeated searches failed to produce any organic material for dating purposes. Nevertheless, it is apparent that the east face of the Yulongxue Shan experienced an earlier and significantly more extensive glaciation than the Yulong Glaciation. It is given the preliminary name Lijiang Glaciation, thereby retaining a part of JEN's glacial nomenclature, although based upon quite different evidence.

Conclusion

Despite lack of any absolute dating, Table 2 provides a preliminary relative chronology and terminology for the glaciation of the Yulongxue Shan. While earlier glacial episodes may have occurred no evidence of such was found. The very recent uplift of the Hengduan Mountains as a whole, and Yulongxue Shan in particular, may explain the apparent absence of earlier (pre-Würm equivalent?) glaciations. This issue is also relevant to any discussion of the glaciation of the Gonga Shan (cf. MESSERLI a. IVES 1984) whose glaciation chronology is much better known. The general contribution of this paper, therefore, is that it forms a working hypothesis for a three-fold glacial chronology of the Yulongxue Shan – pre-Yulong Glaciation (= Lijiang Glaciation – age indeterminate), Yulong Glaciation (= late-Würm equivalent), and Neoglaciation. Now that the entire region is open to visitors, it is to be hoped that future work will be able to provide much more detail and, eventually, a much better approach to absolute dating. For this, soils, lake sediments within and close to the Yulong moraine systems, and discovery of datable organic materials within the moraines, are some of the more obvious objectives to pursue.

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