CLIMATIC FLUCTUATION, A SUGGESTED MEANS FOR THE DEVELOPMENT OF LAKE TERRACES, KUNMING BASIN, CHINA

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ABSTRACT. The tectonic lake basins of Yunnan Province, southwestern China, contain lake terraces the origin of which appears to be related to climatic fluctuation during the Quaternary. The Kunming Basin, containing Lake K'un-yang, was formerly enclosed but has since been included in the Yangtze drainage system by stream capture. The lake terraces were produced by an alternation of deposition and erosion controlled by variations in rainfall during the Pleistocene intervals. The more arid intervals provided an excess of coarse debris which, by clogging the lake outlet, caused temporary stabilization of the lake level. Deposition of terrace materials on the basin floor resulted. Subsequent increase in precipitation, however, allowed the lake outlet to clear away the alluvial dam and the lake level was lowered. Repetition of this cycle under the influence of continuous regional uplift developed terraces at successively lower positions within the basin.

INTRODUCTION

Location

THE Kunming Area includes a large intermontane basin and its bordering highlands in eastern Yunnan Province, southwestern China (figs. 1 and 2). It is one of a number of similar basins of tectonic origin characteristic of Yunnan, the majority of which were occupied by lacustrine waters during relatively recent geologic past. The Kunming basin still retains a portion of its original water body in Lake K'un-yang. Other lakes, including Fuhsien Hai, Yang-tsung Hai, and Chilu Hai are present in smaller basins located east and south of the Kunming basin.

The rugged topography of Yunnan Province places mountain barriers and deep, often impassable valleys across all approaches to the Kunming Area. Adequate communication with surrounding regions has never been achieved. Deeply dissected mountainous terrain separates the basin from the Yangtze Kiang 80 miles to the north. The Burma border lies about 250 miles to the west, the topography in this direction becoming increasingly mountainous and culminating in the southward continuation of the Himalaya arc along the valleys of the Salween and Mekong rivers. The French Indo-China border is located 150 miles to the south, the surface in this

direction being dissected by a maze of deep canyons. The distance from the Kunming Area to the French Indo-China coast is approximately 400 miles.

Climate

The climate is a subtropical monsoon type, the controlling factor being altitude rather than latitude (Jen, 1948). The lake basin stands at 6400 feet, this elevation producing a more temperate climate than is normal for this latitude in Asia. According to Cressey (1934, pp. 373-374) the average minimum temperature is 4° C. and the average summer maximum is 26° C. Seasons are based on wet and dry contrasts rather than temperature differences. Torrential storms occur from May through October, accounting for most of the yearly average precipitation of approximately 40 inches. Strong southwesterly winds characterize the dry winter months and produce local duststorms where moisture and vegetation are scanty. Some believe these storms to have been active in the topographic development of the basin areas since late Tertiary (Brown, 1914). The advent of cold, arid conditions in the Asiatic interior during the Pleistocene is thought to have increased wind activity in Yunnan. A further inference is that the alternation of wind and water action during the dry and wet seasons has been largely responsible for the thick section of fine and coarse clastics which underlies the basin floors.

PHYSICAL SETTING

Topography

The Kunming basin is an elongate, lacustrine plain with dimensions of approximately 35 miles in a north-south direction and a width of 10 to 12 miles (fig. 1). Lake K'un-yang, approximately 25 miles long and 5 to 7 miles wide, occupies the western half of this plain. The surrounding country is prevailingly mountainous, rising to 8000 feet in some localities, and with the relief reaching 2000 feet. The basins and intervening mountains show a definite northeast-southwest alignment. One particularly high ridge parallels the western edge of Lake K'un-yang, presenting a precipitous escarpment known locally as the Sin Chang Cliffs (fig. 1 and plate 2, fig.

2). A broad alluvial flat, barely above the present lake level, intervenes between the lake and the mountainous country to the north, east and south (plate 1, fig. 2). Several alluvial terrace remnants occur at elevations from 10 to 100 feet above the present basin floor along its eastern side.

Drainage

The basin is drained from the southwestern portion by the P'u-to Ho, tributary to the Yangtze Kiang (fig. 1). This single outlet passes through the high Sin Chang Cliffs in a deep, narrow valley. The direction of flow of this stream is first northwestward and then northward to the Yangtze Kiang. Other, more minor streams, dry during much of the year, drain into the basin from the surrounding highlands. Solution activity in the uplands has produced a near-karst topography in many localities.

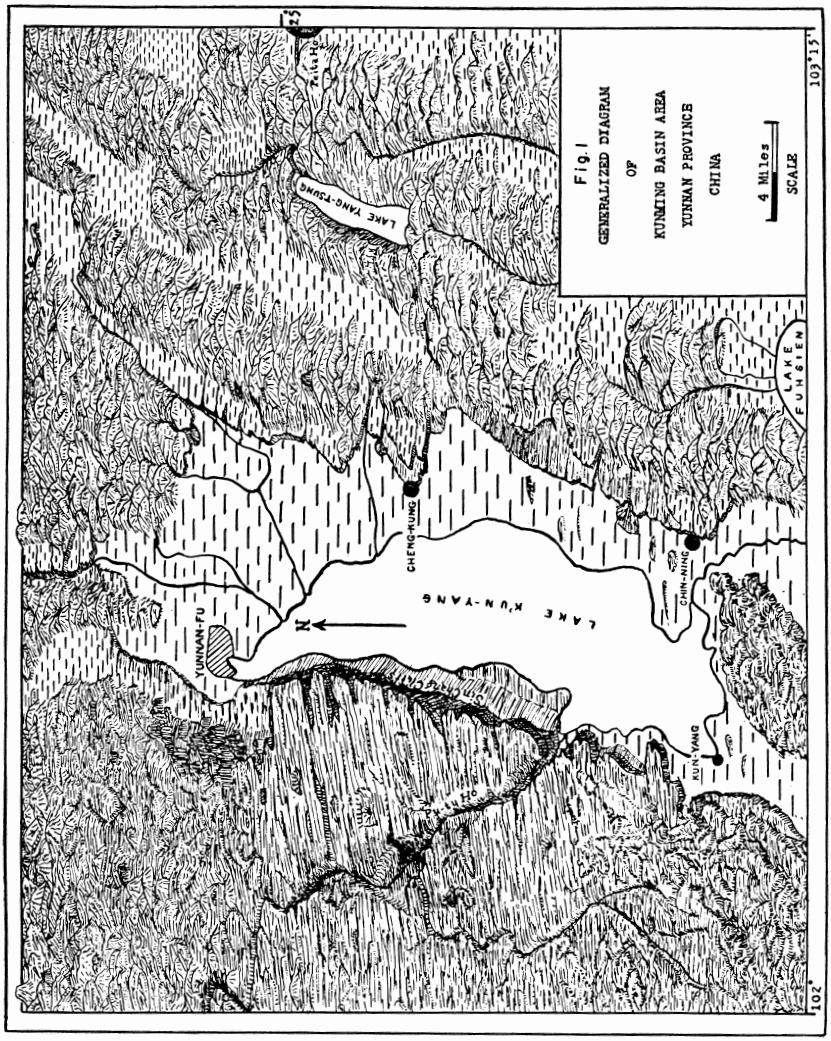
A major drainage divide follows the crests of the ridges east, south, and west of the basin. The runoff east and south of this divide reaches the Peita Ho, tributary to the Hung-shui Kiang (fig. 1). Yang-tsung Hai, Fuhsien Hai, and Chilu Hai drain into the Pieta Ho. The drainage west of this divide is southward into the Yuan Kiang system. Within the basin the runoff is northward into the Yangtze Kiang via the P'u-to Ho, as mentioned above.

An outstanding relief characteristic is the great depth and narrowness of the stream valleys. The P'u-to Ho flows in a precipitous canyon, 2000 feet deep in places. At its juncture with the Yangtze Kiang, relief is in excess of 8000 feet. Minor valleys are also deep and narrow.

It is quite apparent that thorough integration of the drainage has not been accomplished. Lake K'un-yang was originally fed in part by an eastward-flowing P'u-to Ho. This stream was captured by a headward-working tributary of the Yangtze Kiang, reversing the direction of flow and providing an outlet for the lake (fig. 1). Other examples of stream capture are indicated by the barbed appearance of tributary streams in the basin vicinity.

Rock Outcrops

Rocks ranging in age from Cambrian through Quaternary outcrop in the Kunming Area (Brown, 1914). Of these only



Late Paleozoic and Quaternary strata are sufficiently widespread to be of topographic importance. Exposures of Cambrian sandstones and shales, for example, occur only where faulting activity has brought them within the scope of vertical dissection.

Late Paleozoic (Middle Carboniferous) sandstones and limestones form low ridges above the lacustrine plain south of

Lake K'un-yang near Chin-ning and Kun-yang and between Chin-ning and Cheng-kung southeast of the lake (fig. 1). The P'u-to Ho outlet north of Kun-yang is floored with these rocks. Other exposures occur in the basal portions of escarpments north of Yunnan-Fu and west of Lake Yang-tsung.

Most of the country west of the basin is underlain by limestones (Upper Carboniferous), strata also largely responsible for the near-karst topography north of Yunnan-Fu. Exposures of these rocks occur in the base of the Sin Chang Cliffs west of Lake K'un-yang, the upper portion being composed of similar but younger limestones (Permo-Carboniferous) (plate 2, fig. 1). Much of the highland area north, northeast, and east of the lake basin is underlain by the latter limestones with local outcrops of lava, shale, and sandstone.

The basin floor is underlain by Quaternary lacustrine deposits consisting of interfingering layers and lenses of unconsolidated clay, silt, sand, and gravel. Lignitic concentrations occur throughout. Local accumulations of gravel and cobbles indicate deposition by torrential streams. Alluvial fans are present at points of debouchment of stream channels along the basin sides. Finer clastic materials are found in the deltaic projections of the lake shore, as at Yunnan-Fu, Cheng-kung, Chin-ning, and Kun-yang (fig. 1).

Quaternary terraces along the eastern side of the basin are lithologically similar to the more recent deposits of the basin floor. These are dissected remnants of old fluvio-lacustrine plains, each representing an interval of alluvial fan and deltaic construction during a temporary halt in lake-level subsidence. Detailed examination was not possible at the time of collection of data for this paper. However, the undulatory appearance of the terrace surfaces and the character of the deposits lends this thesis greater strength than mere assumption. Additional study may show a relationship between the lake terraces and fluvial terraces further downstream in the Yangtze drainage system.

Observations made in the lower hills along the eastern side of the basin, at somewhat greater elevation than the highest terraces, revealed the presence of disoriented, tilted blocks of thinly bedded, silty clays, sandstones, and lignitic layers of semi-consolidated nature (plate 1, fig. 1). These strata occur at lower elevations than the Paleozoic limestones which con-

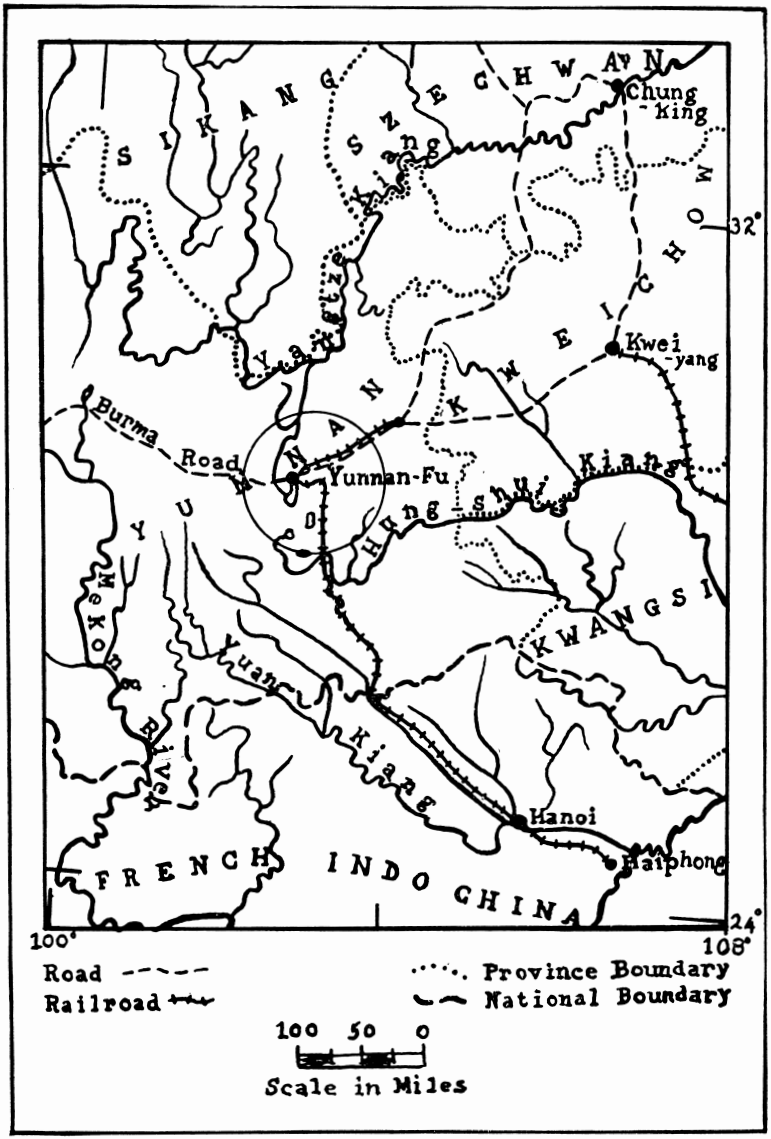


Fig. 2. General map of southwestern China showing major drainage lines and existing communications.

stitute the higher ridges. The beds contain unidentified vertebrate remains and, according to local scientific opinion, are upper Pliocene. The jumbled attitude is the result of faulting.

SUGGESTED PHYSIOGRAPHIC DEVELOPMENT

The rugged, deeply dissected terrain, with steep, relatively fresh-appearing escarpments, favors belief that the Kunming Area is tectonically active at present. Further evidence is found in the modern earthquake record (Cressey, 1934, p. 36). The structural trends of the region, according to Lee (1939, p. 309), are approximately north-northeast and south-southwest, this also being the alignment of the lake basins. The south China region is believed by Lee to have been folded and elevated in late Mesozoic time, the modern basins being of tectonic origin aligned along the axes of folding.

Brown (1914, p. 115) postulated a late Tertiary age for the inception of the modern topographic development, the lake basins having been formed by faulting toward the close of Pliocene. Perhaps old zones of weakness produced by the late Mesozoic folding provided a locale for late Pliocene tectonics. The present bold relief is the result of uplift and faulting, with accompanying stimulation of erosional agencies down through the present. Deprat, as quoted by Lee (1939, p. 206), claims abundant evidence for recent uplift in Yunnan of as much as 6500 feet, though this figure would seem excessive. There can be little doubt, however, that uplift is occurring. The narrow, deep valleys, a dominant topographic element in the region, indicate a continuous stimulus to stream erosion. Furthermore, the lake basins are being tapped and gradually drained as the deepening valleys encroach into these formerly enclosed areas. The steep, 2000-foot Sin Chang Cliffs, in the present writer's opinion, represents only slight modification of a fault scarp along which faulting may still be potential (plate 2, fig. 2). The tilted blocks of Tertiary sediment (Pliocene ?) along the eastern side of the basin show that faulting occurred subsequent to deposition of these strata.

Brown (1914, pp. 118-119) recognized evidence for several stages in the tectonic and erosional history of the region. He cited an accordance of summits east of Lake K'un-yang as representative of a late Pliocene erosion surface, the Tanghien erosional stage of Willis (1907, p. 99). A rather noticeable widening in the upper portion of the P'u-to Ho valley walls is also pointed to as a relic of this stage. This interval was presumably one of broad valley development which, accord-

PLATE 1

Fig. 1. Panorama of the Kunming basin from the east. The high rimming hills are visible in the background. Late Tertiary sediments (Pliocene ?) occupy the immediate foreground.

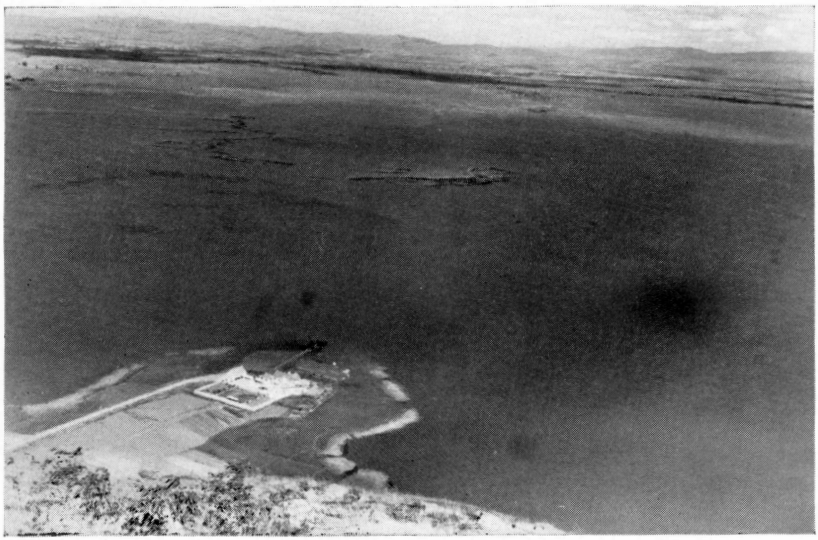


Fig. 2. View eastward from the Sin Chang Cliffs across Lake K'un-yang. The flat lacustrine plain with terrace remnants standing slightly higher is visible in the background.

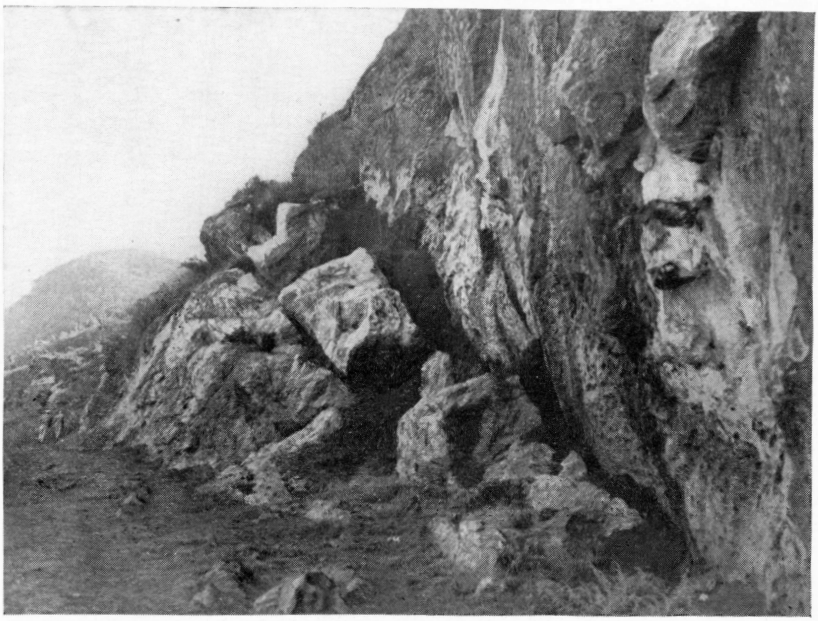


Fig. 1. Steeply westward-dipping Permo-Carboniferous limestones in the upper portion of the Sin Chang Cliffs west of Lake K'un-yang.

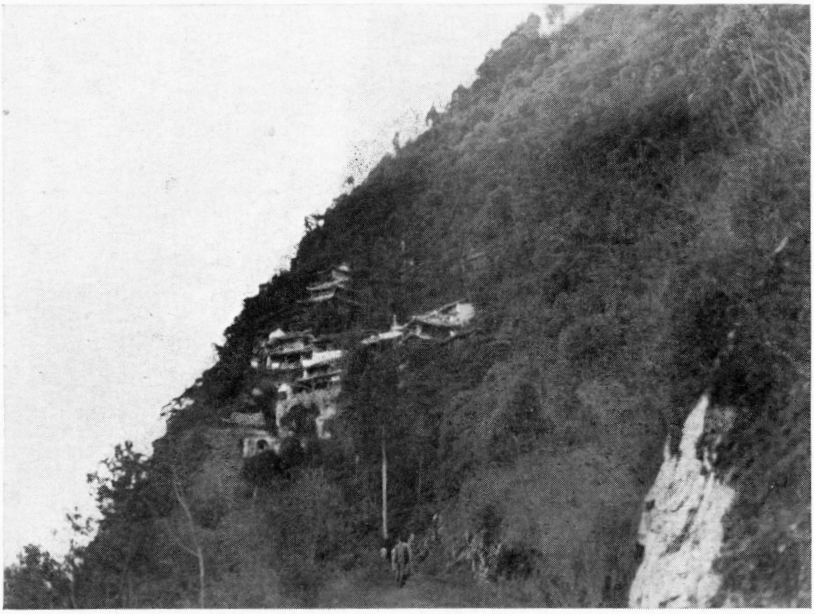


Fig. 2. View south along the Sin Chang Cliffs which rim the western edge of Lake K'un-yang. This escarpment is a fault scarp only slightly modified by erosion. The outcropping strata, Permo-Carboniferous limestones, dip westward into the face of the cliff.

ing to Brown, was terminated by faulting and basin development. In early Pleistocene these basins accumulated lacustrine and fluvial deposits, this being the Hinchou aggradational stage of Willis. This phase is reputed to be in progress at present in the Yunnan region.

The present uplift and drainage adjustment, placed by Brown in the Fon Ho stage (Willis, 1907), may have had its origin in late Pliocene or early Pleistocene. The establishment of drainage systems, deepening of valleys with uplift, and the tapping of the lake basins are the results of this activity. The diversion of Lake K'un-yang into the Yangtze Kiang system, as well as capture of the Yang-tsung, Fuhsien, and Chilu lake drainages, are thought to have been part of this process.

Deprat (Brown, 1914, p. 122) contended that in eastern Yunnan the interval from late Pliocene to the present is divisible into five erosional episodes, separated by periods of relative stability. The present writer does not have sufficiently detailed evidence to refute or support this contention. Critical examination of the Yunnan lake terraces should divulge important facts. A thorough study of the hydrographic development of late Tertiary and Quaternary time is needed.

A relationship suggested is the correlation of lake terrace development with regional climatic fluctuations. Harland (1943), working in western Szechwan north of Yunnan Province, found evidence favoring climatic change during the Pleistocene. Lee (1939, pp. 367-399) also favored this view. Cotton (1944, pp. 272-274), in review of a paper by Richardson (1943) concerned with terraces in western Szechwan, suggested that the terrace gravels along the river valleys may have been deposited during the moist intervals when the supply of debris to the drainage was at a maximum. As precipitation decreased in a subsequent drier interval vertical incision of these deposits occurred. The increased erosive power of the runoff, despite a decrease in rainfall, is attributed to the lessening in quantity of debris supplied by weathering. Repetition of such alternating conditions, along with continuous uplift, resulted in terracing of the valley bottom deposits.

The present writer is in sharp disagreement with this suggested sequence of events. Field data gathered in somewhat similar climatic regions in North America fosters a different view (Tator, 1949). In a region of continuous uplift moist

intervals are times of increased drainage incision, the runoff being less hampered by excess of clastic load. Interstream slopes are temporarily stabilized by the increase in vegetative cover. Chemically controlled weathering processes predominate, the result being that the products are of finer nature. Runoff, fed by the more uniform precipitation, is constant. Drainage lines, unhindered by the clogging effect of coarse debris, are able to maintain permanent channels. On the other hand, minimum downcutting prevails under arid conditions. Decrease in precipitation reduces the vegetative cover thereby decreasing the stability of slopes. Physically controlled weathering produces coarse detrital fragments. Rainfall is less uniform, in fact, is usually torrential and of spasmodic occurrence. Runoff is intermittent and the drainage lines become choked with debris. The streams experience difficulty in maintaining a single line of flow, the latter being a requirement for deep valley incision.

Such could have been the history of the development of the Kunming basin terraces. Intervals of greater moisture caused drainage incision and lowered the lake level. Greater aridity, however, temporarily stabilized the lake level as the outlet became clogged with debris, causing accumulations of fluviolacustrine material on the floor of the basin. A succeeding, more humid interval then led to clearing of the outlet and lowering of the lake level. Repetition of this process may have yielded the terrace sequence. The vertical spacing between successive terraces would be controlled by the rate of uplift and the duration of the moist episode whereas the thickness of the individual terrace deposits would indicate the length of the drier climatic phases.

It is believed that the pre-Pleistocene climate in this part of Asia was arid to semi-arid. The incidence of glaciation was brought about by increased precipitation on the higher mountians of western China. It is not illogical to expect that peripheral areas to the south and east of the centers of ice accumulation must also have been affected. Thus, while the glacial stages were perhaps times of increased precipitation, the interglacial stages may have been times of climatic shift toward normal, or aridity.

SUMMARY

The Kunming basin includes a broad lacustrine plain fringed by lake terraces and enclosed by rugged, mountainous terrain. The surrounding highlands are underlain for the most part by late Paleozoic limestones, dissection of which has produced a near-karst topography. This region has been orogenically active since late Pliocene and uplift is still in progress. The basin formed in late Pliocene or early Pleistocene along structural trends established during the late Mesozoic. Capture of the drainage of the basin was accomplished by a tributary of the Yangtze Kiang system in early Pleistocene. Under the influence of continuous uplift and moist climatic intervals, perhaps during the glacial stages, the level of Lake K'un-yang has been progressively lowered. Each lake terrace represents an interval of temporary stabilization of lake level due to alluvial damming of the outlet under a more arid climatic regime. It is felt that the more arid episodes may correlate with interglacial stages. If this sequence of events should prove adequate to account for the Kunming basin terraces it should also be applicable to the other basins of southwestern China.

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