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LESZEK LINDNER

# The age of the Bande Amir travertines in Afghanistan

ABSTRACT: In the upstream reach of the Bande Amir valley in the West Hindukush range in Afghanistan there occurs a system of lakes separated each other by travertine dams of the Haybat Series. Analyses of plants and malaco-fossils as well as radiocarbon datings prove their Late-Glacial and Holocene development continued until the present days. The ancient travertine series (Paner and Yakhak), preserved at the valley slopes, have been deposited during the interglacials Mindel/Riss and Riss/Würm.

## INTRODUCTION

In the western part of the Bande Amir valley, West Hindukush in Afghanistan, a system of five, world-famous dammed lakes, of an unusually picturesque landscape developed in successive cascades (Text--figs 1 and 2). Starting from the west, the first and the lowermost is the Bande Gholaman Lake (2 887 m a.s.l.); higher up there appear the lakes: Bande Amir (2 916 m a.s.l.), Bande Haybat (2 940 m a.s.l.) and Bande Paner (2 971 m a.s.l.). The Bande Jadacel Lake (3 030 m a.s.l.) is located at the greatest altitudes. The investigations in this region were kept by the present author in summer 1977.

## GEOMORPHOLOGIC SETTING

In the south-western Hindukush foreland there extends a vast plain composed of slightly south-westwards dipping Upper Cretaceous marly--sandstone marine sediments, over 700 m thick, covered by several

metre thick Neogene marly conglomerates. The plain occurs at 3 300—3 600 m. a.s.l. and is bounded in the south by the Kohe-Baba massif. The central part of the plain is cut by a canyon-like, 500—600 m deep, upstream reach of the Bande Amir valley (Text-fig. 1 and Pl. 1, Fig. 1), belonging to the Amu-Daria drainage system.

According to Jux & Kempf (1971), the area of the investigated fragment of the Bande Amir drainage basin can be estimated for 410 km² and so, with a mean precipitation of 450 mm annually, it is supplied with about 185 million cubic metres of water. But there is a considerable varying seasonal distribution of the precipitation, and the greatest water supply is noted in early summer when rivers and lakes start refreezing and when snow and ice covers of the Kohe Baba massif are quickly melting (Pietruszka & Szarejko 1980). In a water balance of this valley fragment, a considerable part is also played by evaporation as the area is under a desert-steppe climate. A snow cover occurs since November until May and many a time it is 2—3 m thick. In other months, at a common cloudless sky, the daily air temperature reaches 30°C but at night it can drop down below 0°C. The lake water is cold in summer too and its temperature is below 15°C at the surface whereas in deeper layers it may even drop down to 4—5°C. The water contains much calcium carbonate that is precipitated (sinters, travertines) in summer, first of all on alive and dead water vegetation and in zones with a more intensive flow and turbulence that favour a loss of $CO_2$.

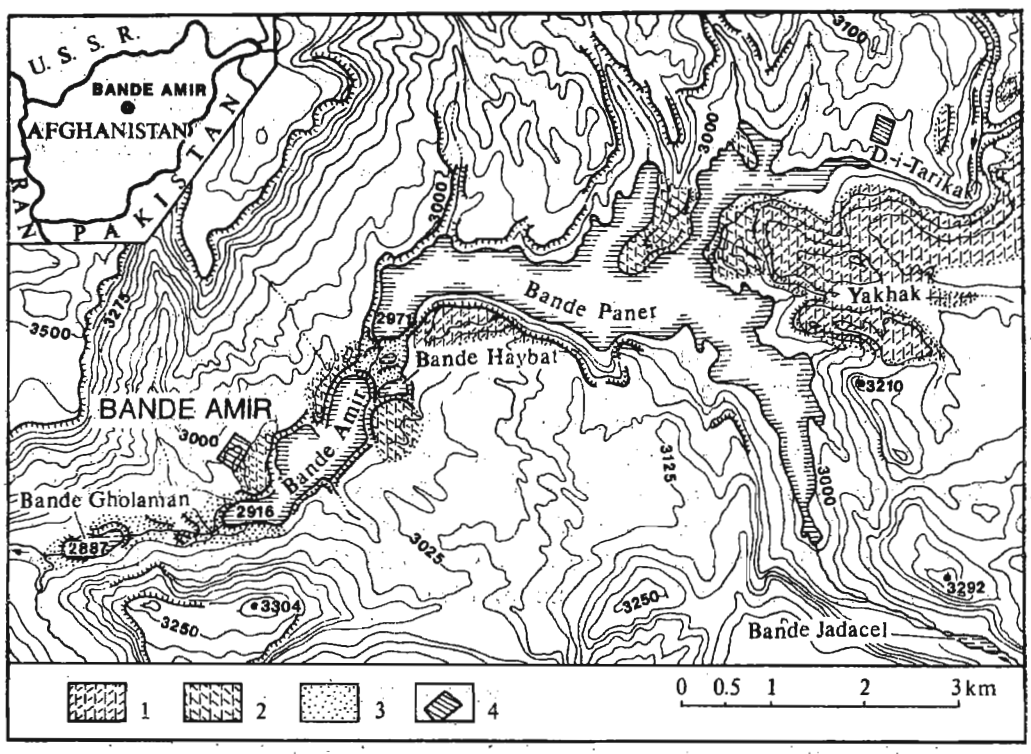


Fig. 1. Location of the investigated Quaternary travertines in the Bande Amir valley (*after*: Jux & Kempf 1971, Lindner 1979)

*1* Yakhak series, *2* Paner series, *3* Haybat series, *4* small villages

## RECENT TRAVERTINE DAMS (HAYBAT SERIES)

The four lakes located at lower altitudes (Bande Gholaman, Bande Amir, Bande Haybat and Bande Paner) have been formed due to partition of the valley by travertine dams of the Haybat Series (Pl. 1, Fig. 2 and Pl. 2, Figs 1—2). This series is composed of calc-sinters and travertines with inserts of limy sands, lake marls, gyttja, peat and Yakhak series (Jux & Kempf 1971, Lindner 1979). The highest lake (Bande Jadacel) forms a fragment of a reservoir created during the growth of the ancient travertine series, now dissected and preserved at 126 m above the valley bottom (Yakhak Series).

The sediments of the Haybat Series that enabled a formation of the four lower lakes, form the dams that usually connect the both slopes of the valley. These dams are 5—15 m high and several metres wide. Locally, they form arched ridges (Pl. 2, Figs 1—2 and Pl. 4, Fig. 2) and only in the zone between the lakes Bande Amir and Bande Paner they form sinter-like cascades that cover the thresholds composed of Upper Cretaceous sandstanes (Pl. 3, Figs 1—2 and Pl. 4, Fig. 1). In most cases the dams display an asymmetric transversal section. The slopes towards the lakes are very steep and even overhung whereas from the outer side they have a profile of a steep cone. In many places, usually at dam tops, the lake waters are overflowing through numerous fissures and tunnels into lower valley fragments. Downstream the dam of the Bande Amir Lake (Pl. 2, Fig. 2) the waters are regulated and used for turbine mills, typical of this part of Asia. At the tops of the dams there grow not very dense willow scrubs and high grasses.

A location of the dams and an accumulation of travertines and sinters are connected with the places of primary and more active now water runoff in these parts of the Bande Amir valley where it passes along gaps formed through the Upper Cretaceous sandstones (Pl. 3, Figs 1—2

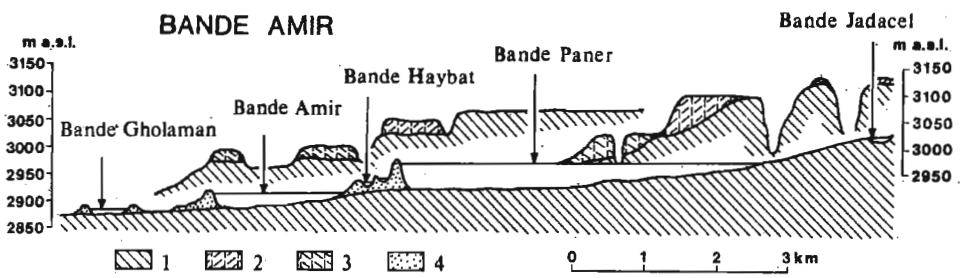


Fig. 2. Longitudinal section of the investigated part of the Bande Amir valley, to show location of the dammed lakes and Quaternary travertines

1 Upper Cretaceous marls, limestones and sandstones, 2 Yakhak series, 3 Paner series, 4 Haybat series

and Pl. 5, Figs 1—2). Instead, present location of these lakes is connected with zones where there are exposed really softer and more easily weathered and dissoluble Upper Cretaceous marls.

Downstream the Bande Amir Lake, in a sequence of the dams included into the Haybat Series, a succession of rhythmically repreated layers was noted, composed of a travertine and limy sands with shells of *Pisidium, Lymnaea* and *Gyraulus;* beneath a bed of this type, a thin insert of peat and limy gyttja was found within a lake marl. Jux & Kempf (1971) presented three radiocarbon datings of these sediments: the lowermost sample, coming from a gyttja, contained a considerable content of pine pollen grains and was dated for 850±425 years B.P.; the middle sample came from the overlying lake marl with *Lymnea* and was dated for 13 235±170 years B.P.; the uppermost sample came from a peat that occurred still higher up and was dated for 1 065±170 years B.P.

According to the present author, the age determination of the middle sample seems to be too high (*see* Text-fig. 3 where this dating is transplaced as indicated by the arrowed dashed line). Jux & Kempf (1971) suggested this fact to be a result of an enrichment of the sample in a matter washed out from slightly older travertines af the Haybat Series in the upstream part of the valley.

An accumulation of the series and therefore, an initial moment of the formation of dammed lakes in the Bande Amir valley, must have been started during an amelioration of climatic conditions at the end of the Würm Glaciation, probably during the Bølling Phase and it has been lasting up to Recent times.

## REMNANTS OF OLDER TRAVERTINE DAMS (PANER AND YAKHAK SERIES)

The Paner Series is represented by an older travertine complex that formed once a system of several-step dams. Due to younger erosive processes the travertines were removed from the axial parts of the valley and presently are exposed only at its slopes, about 75 m above the level of the Bande Amir Lake and about 60 m above the level of the Bande Paner Lake (Text-figs 1—2 and Pl. 6, Figs 1—2). Similarly as in the case of the Haybat Series, the Paner Series has been formed at and due to a presence of rock thresholds composed of hard Upper Cretaceous sandstones. But the travertines, the Paner Series is composed also of beds of a lake marl and limy sands as well as of thin inserts of gravels that include limy and sandstone pebbles. The gravels contain also single quartzite and shale pebbles, coming probably from a greater distance or from a washed Neogene molasse of the adjacent regions.

In places where the series contains thick lake marl beds, the latter include habitable niches and caves, done probably by the buddhist monks

(XI*th*—XII*th* centuries A.D.). Some of them are used now by the shepherds as shelters (*e.g.* to the north-west of the Bande Amir Lake). The mentioned beds contain a rich set of malacofossils, among which Jux & Kempf (1971) determined *Lymnaea peregra* var. div., *Valvata piscinalis*, *Gyraulus* sp., *Oxyloma elegans*, *Lymnaea truncatula*, *Pisidium* sp., and others associated with frequent ostracodes. Numerous impressions of branches and leaves, preserved within the analyzed sediments, prove that at the time when the Paner Series formed a lake dam, the latter was mainly overgrown by willows (*Salix*), *i.e.* similarly as today.

The analysed series contains two distinct gravel horizons. The first forms the basis of the travertine complex whereas the other overlies the complex. The lower gravels prove an erosion before the accumulation of the travertine complex, whereas the upper gravels resulted from a dissection and a considerable destruction of the Paner Series that partitioned once the Bande Amir valley by a system of older dams. From a climatic point of view, it seems probable, as suggested by Jux & Kempf (1971) that the lower gravels represent a cool period, with a high precipitation and so, favorable for development of mountain glaciers. A travertine complex separating the gravels, corresponds with a warm period, probably warmer than today, whereas the upper gravels correspond with an erosive cycle connected with a younger glacier advance.

The above interpretation is supported by radiocarbon datings (Jux & Kampf 1971) of two samples coming from a lake marl of the Paner Series (Text-fig. 3): one sample coming from a section north of the Bande Amir Lake was dated for 31 375±440 years B.P. whereas that one from the uppermost part of the Paner Series, sectioned north-east of the Bande Paner Lake, was dated for 25 425±700 years B.P. (Jux & Kempf 1971). These datings prove that the both analysed sediments (in a distance of over 6 km from each other) have been deposited during the same climatic-sedimentary cycle. As the datings are concerned with the upper part of the Paner Series, an accumulation of the travertines of this series must have lasted until the Middle Würm interstadial warming whereas it had been started at the end of the Riss Glaciation. The most favorable conditions for the accumulation of the travertines occurred during the Riss/Würm Interglacial. Consequently, the upper gravels correspond with a glacial part of the Würm and the lower gravels prove an erosive-depositional fluvial activity during the maximum glacier advance of the Riss Glaciation.

The Yakhak Series occupies the greatest area to the east of the Paner Lake (*cf.* Text-fig. 1) where it occurs at about 126 m above the lake water level. But travertines, it is composed of a lake marl and gravels that form distinct, locally cemented beds along the shores of ancient lakes. These gravels contain mainly the pebbles of limestones, quartizites,

sandstones and shales. Similarly as in the case of the older series, the Yakhak Series is genetically connected with ledges of Upper Cretaceous sandstones that form thresholds and rapids in this part of the valley.

As proved by field observations, the Yakhak Series is locally over 50 m thick. At its bottom there are gravels, overlain by 20—30 m thick lake marl with numerous ostracodes and inserts of limy sands, many a time interbedded with travertines. At the top of the sequence there appear gravels that can be correlated with the overlying fluvial sediments preserved in the Darya-i-Tarikak valley. They probably correspond with the highest river terrace (30—50 m) in the valleys that dissect the western part of the Hindukush (Khinjan, Doszi region).

A principal part of the travertine-lacustrine complex of the Yakhak Series seems to have been deposited during the Mindel/Riss Interglacial.

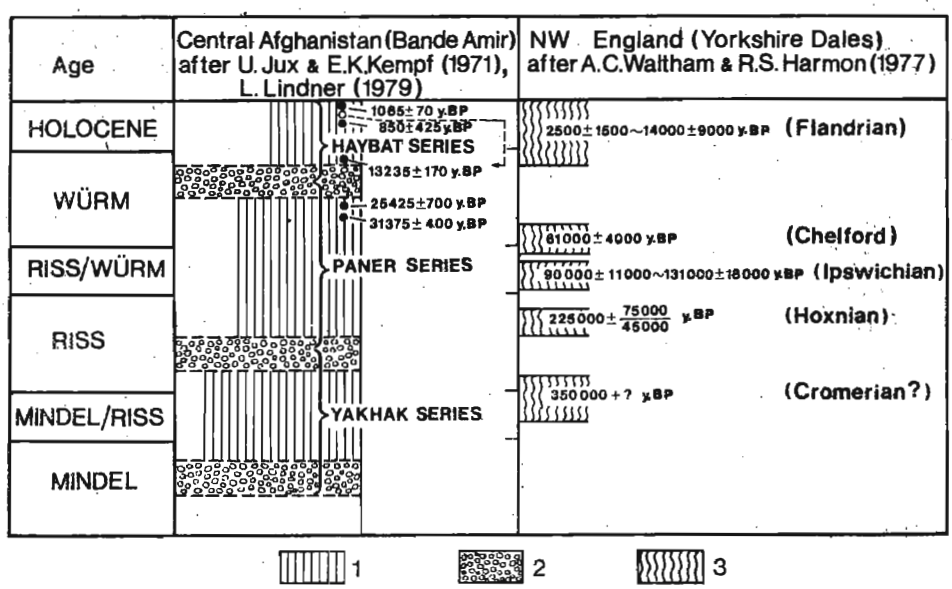


Fig. 3. Stratigraphic correlation of the Bande Amir travertines and calcareous flowstones from the Yorkshire Dales caves in England

*1* travertine deposits, *2* gravels, *3* calcareous flowstones,

The overlying gravels, noted also in the upstream part of the valley, correspond at the same time with the gravels that underlie the Paner Series and represent a period probably simultaneous with a maximum glacier extent during the Riss Glaciation. Instead, the gravels that underlie the travertine-lacustrine complex of the Yakhak Series, should be the trace of an intensive valley overflow during the Mindel Glaciation.

## DISCUSSION OF THE AGE

The described sediments enable to recognize a presence of two cold intervals (Riss and Mindel), preceding the Würm and of two separating warm periods of the interglacial rank in central Afghanistan (Lindner 1979). The collected data are insufficient for a reconstruction of climatic changes in the older Quaternary.

A hypsometrical localization of the investigated area (2 800—3 600 m a.s.l.) caused that the Late Pleistocene lowering of the snowline in this part of Asia, even about 800—1 000 m referring to its present position at 5 000—4 800 m a.s.l. (Velitchko & Lebedeva 1973, Pietruszka & Szarejko 1980, Furmańczyk & *al.* 1980), made a development of the mountain glaciers impossible. But an absence of morainic sediments does not exclude a possibility of periglacial processes in this area. These processes are proved by a presence of well developed structural soils and thuphures at the surface of the Upper Cretaceous plain, mainly close to the passes that separate the drainage basins of the Bande Amir and Bamyan rivers. During interglacials (Mindel/Riss and Riss/Würm) the conditions were similar to the Recent ones, although during the climatic optima and especially, just after the optima, the vegetation seems to have been more differentiated.

A confrontation of the presented age interpretation of the travertine series with uranium datings of calcareous flowstones from the north-western England (Waltham & Harmon 1977) suggests (*see* Text-fig. 3) that even in such distant regions of the northern hemisphere the main warm periods favorable for precipitation of calcium carbonate appeared more or less simultaneously.

*Institute of Geology*
*of the Warsaw University,*
*Al. Żwirki i Wigury 93,*
*02-089 Warsaw, Poland*

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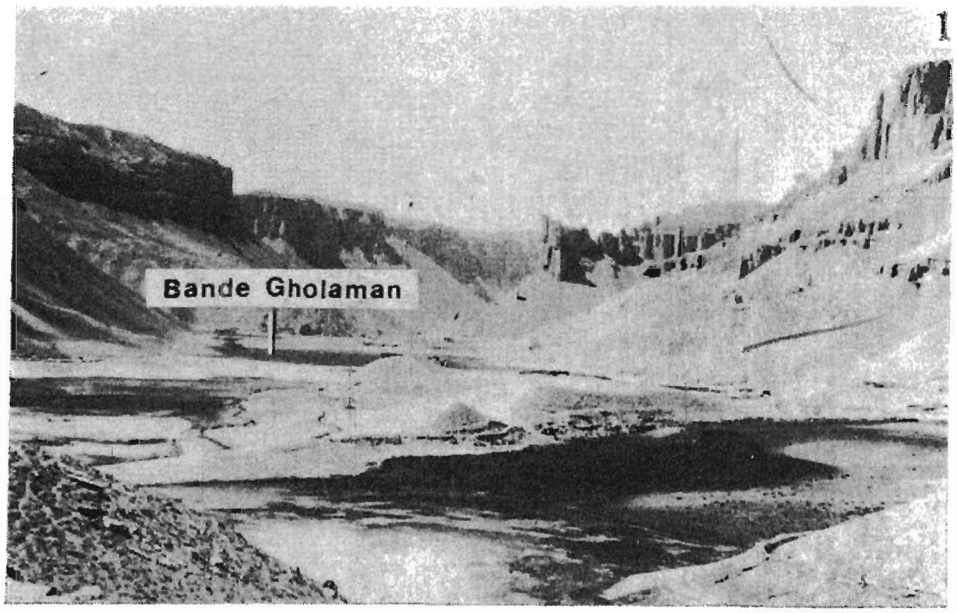
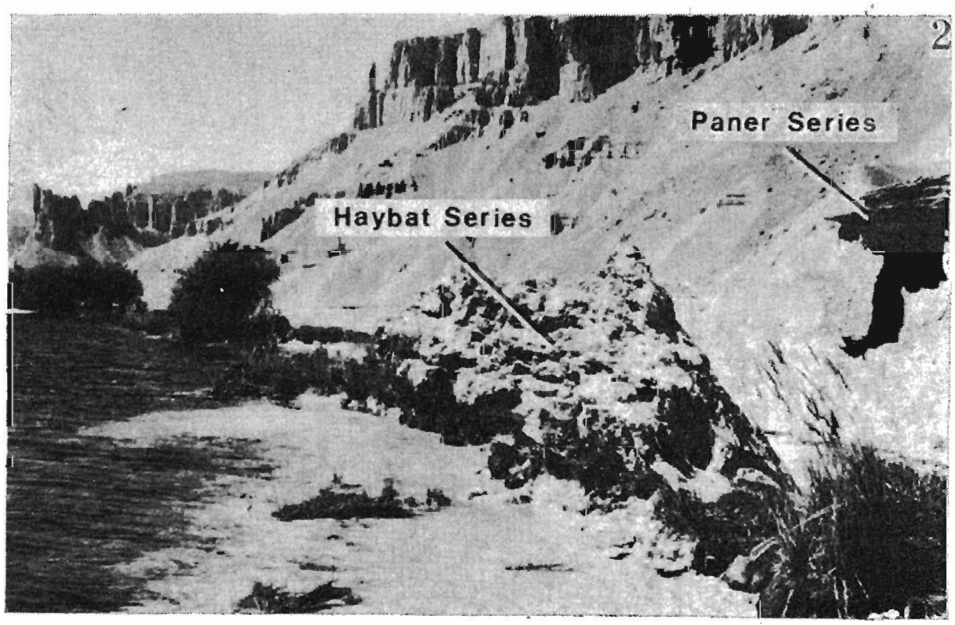
L. LINDNER

# CZWARTORZĘDOWE TRAWERTYNY DOLINY BANDE AMIR W AFGANISTANIE

## (Streszczenie)

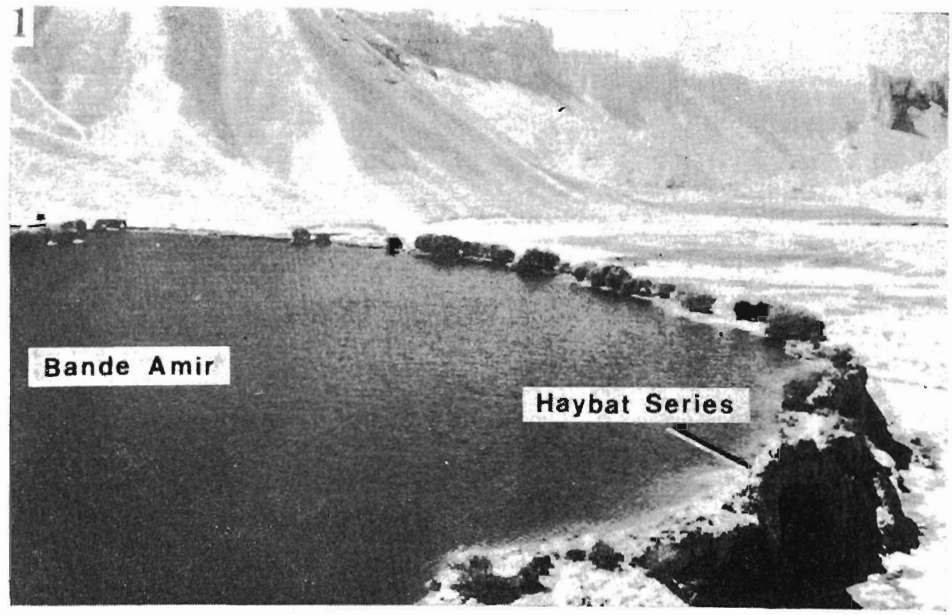
Przedmiotem pracy jest analiza wieku trzech czwartorzędowych serii trawertynowych zachowanych w górnym odcinku doliny Bande Amir rozcinającej obszar zachodniego przedpola Hindukuszu w Centralnym Afganistanie (fig. 1—2). Osady najmłodszej z tych serii (Haybat) datowane są na schyłek würmu i holocen (fig. 3). Osady te tworzą system grobli o wysokości 5—15 m, przegradzających dolinę i warunkujących utworzenie czterech, kaskadowo względem siebie położonych jezior zaporowych (pl. 1—6). Utworzenie starszej serii trawertynowej (Paner), zachowanej ponad współczesnym dnem doliny na wysokości 60—75 m, należy wiązać głównie z interglacjałem Riss/Würm, zaś serii najstarszej (Yakhak), zachowanej na wysokości 126 m, głównie z interglacjałem Mindel/Riss (fig. 3).




1 — General view of the Bande Amir valley; Bande Gholaman Lake visible at the background

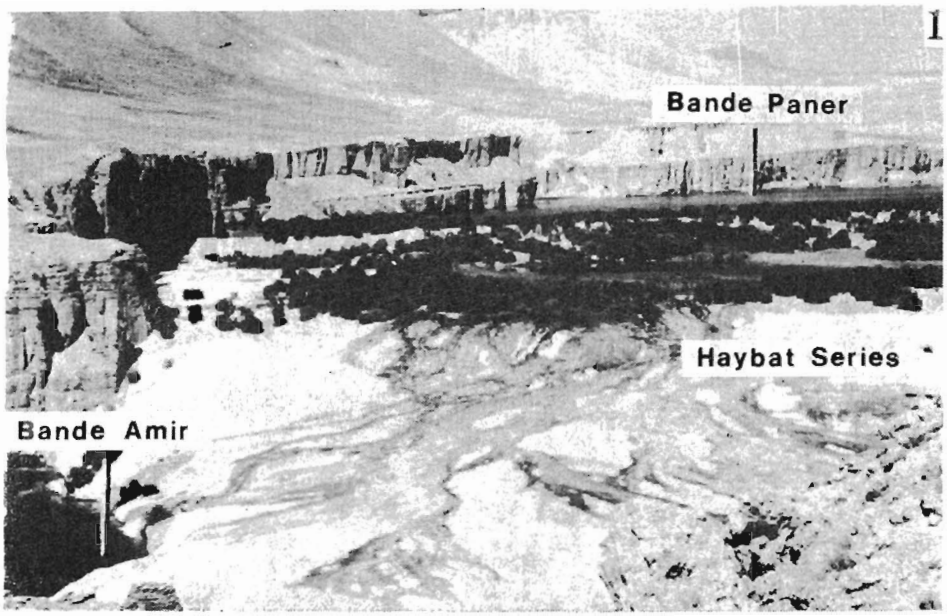
2 — Slope of the Bande Amir valley: at the foreground visible is a travertine dam (built of the Haybat series) which is responsible for the formation of the Bande Amir Lake

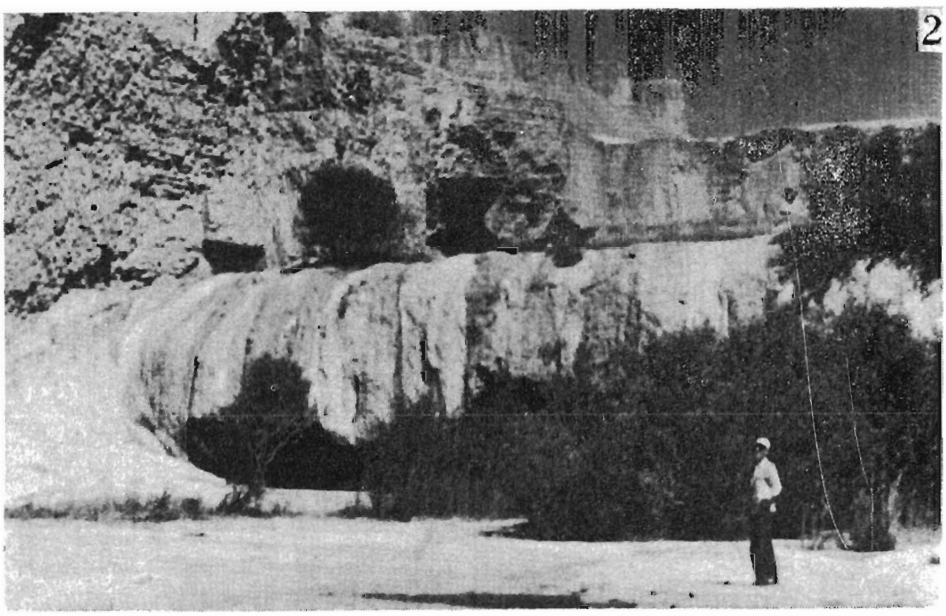




1 — North-western shore of the Bande Amir Lake limited by a travertine dam of the Haybat series

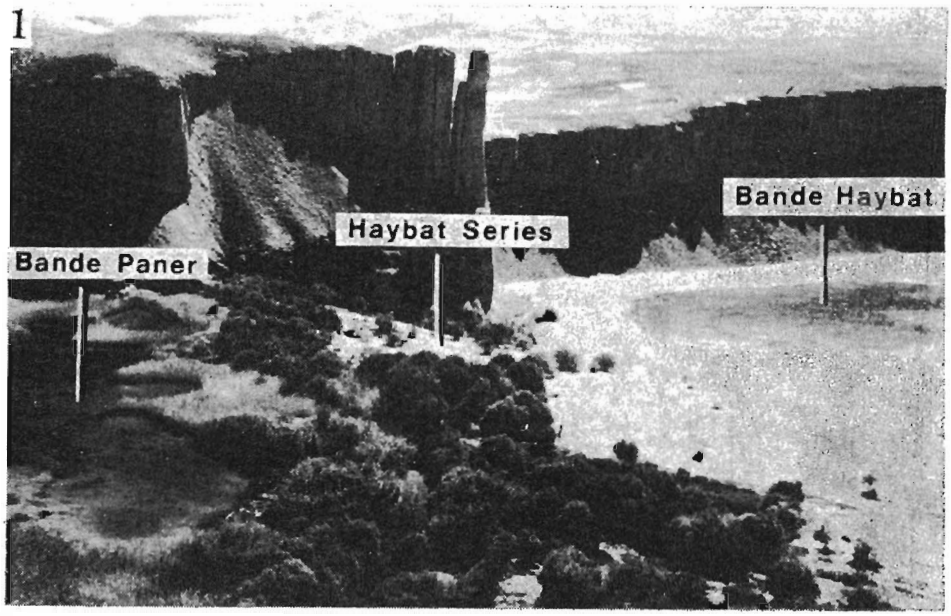
2 — Travertine dam of the Bande Amir Lake; along its feet visible are turbine mills to grind the corn (a)

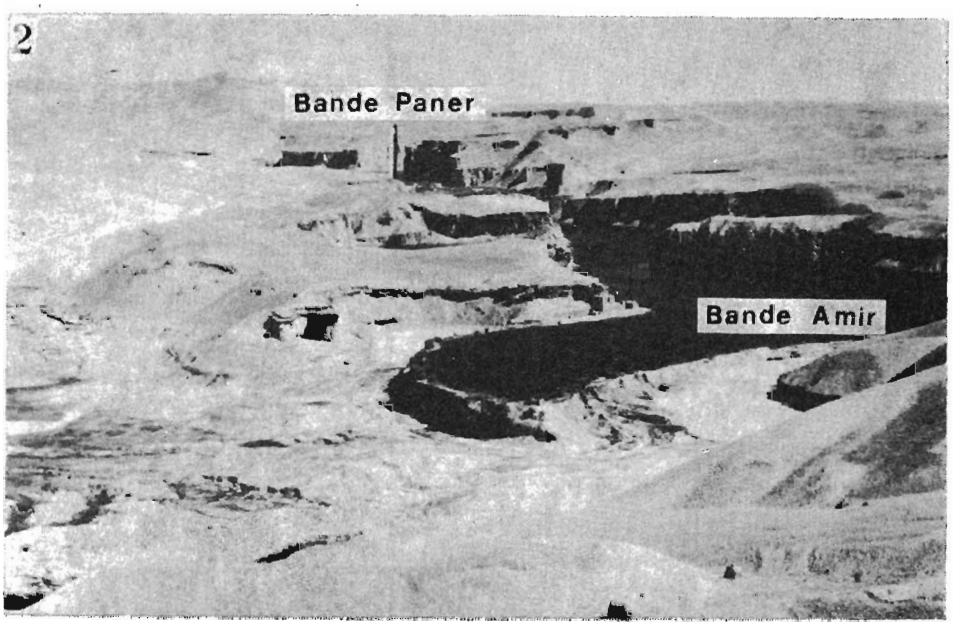



1 — Gap part of the Bande Amir valley with travertines of the Haybat series which separate the Bande Paner Lake from the Bande Amir Lake

2 — Cascades of the calcareous sinter within the dam of the Bande Paner Lake



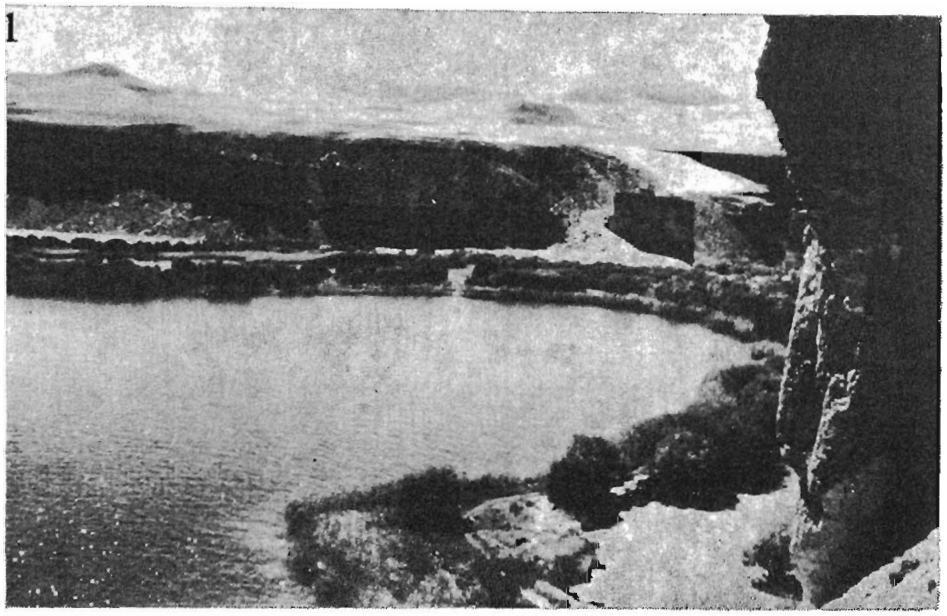

1 — Fragment of the travertine dam (covered by plant vegetation) which separates Bande Paner Lake from the Bande Haybat Lake

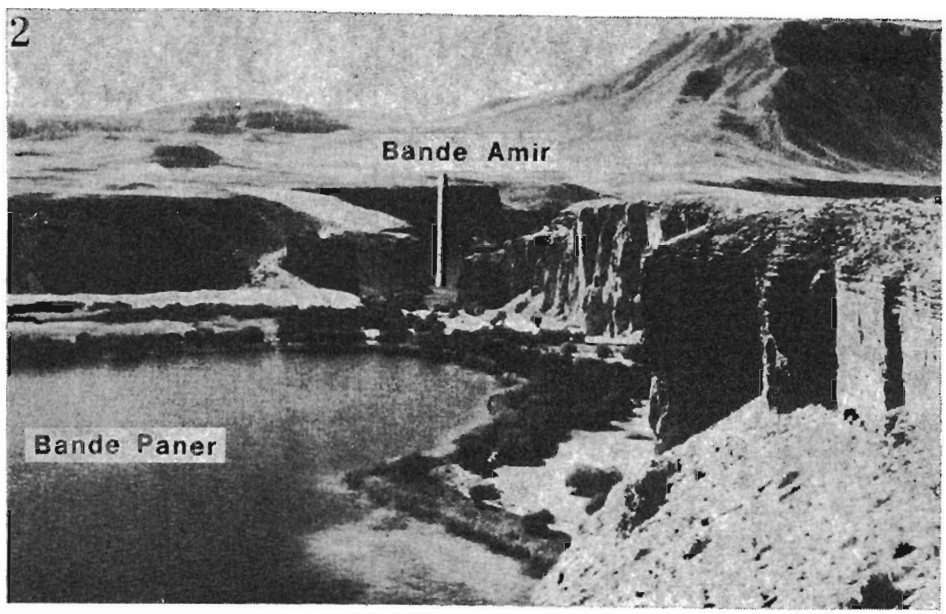
2 — General view of the upstream part of the Bande Amir valley, to show situation of the dammed lakes



1 — Bande Amir Lake; the photo taken from the travertine dam covered by the plant vegetation

2 — North-western shore of the Bande Amir Lake at the place where it approaches the Bande Amir Mosque




1 — Western shore of the Bande Paner Lake limited by a travertine dam (covered by plant vegetation) built of the Haybat series

2 — Another view of the same place: the photo taken from a higher-situated point, to show the Bande Amir Lake visible behind the dam