The Geographical Journal, Vol. **153**, No. 2. July 1987, pp. 205–210

THE BADAIN JARAN DESERT: REMOTE SENSING INVESTIGATIONS

A. S. WALKER, J. W. OLSEN and BAGEN

Approximately half the Badain Jaran Desert in the north-western Alashan Plain of northern China is a sand sea. The remainder is gravel or bedrock. The north-western border of the desert is a playa. The desert has been imaged by both Landsat and the Shuttle Imaging Radar (SIR-A). Landsat analysis indicates there are two dune patterns in the sand sea, north-east oriented crescentic dunes along the northern and western borders, and complex star dunes in the central and eastern desert. Although the orientation and morphology of the dunes are easily visible on Landsat, they cannot be determined with the radar image obtained from the aspect angle used during the SIR-A mission. An abrupt change in wavelength of the dune pattern near the Badain Jaran Playa is mappable on Landsat, but not seen on the radar image. The playa appears to be considerably larger on radar than on the Landsat, and we may be seeing subsurface penetration of dry surficial sands with the radar. Archaeological evidence suggests the playa was the location of prehistoric and historic human activity. SIR-A data indicate the playa was formerly a considerably larger inland lake.

KEY WORDS: Badain Jaran Desert, sand sea, playa, remote sensing, Landsat.

THE BADAIN JARAN IS a 44 000 square-kilometre desert in the north-western Alashan Plain of the Inner Mongolian Autonomous Region, People's Republic of China. Approximately half the desert is a sand sea. The remainder is bedrock or gobi, loose unsorted gravels predominantly of pebble size (4–64 mm diameter). The Alashan Plain is a broad, tectonically stable platform at an elevation between 1000–2000 metres above sea level. Annual rainfall in the Badain Jaran varies from less than 100 mm in the west to about 250 mm in the east (Zhu and others, 1980). The desert is bounded on the west by the intermittent Ruo Shui stream, and on the south by the Qilian Shan (Qilĭan Mountains) and small ranges that separate it from the gobi and sands of the Hexi Corridor. To the north, it merges with black gobi and the plains of the Mongolian People's Republic. The Lang Shan in the east separates the Badain Jaran from the Ulan Buh Desert. The Yabrai Shan separates it from the Tengger Desert to the south. The desert is outlined in Figure 1.

There are at least two sand dune patterns in the Badain Jaran Desert. According to Yu and others (1962), lines of crescentic dunes 3–20 metres high, oriented toward the north-east, are distributed along the northern and western borders. These investigators state that the prevailing wind is from the north-west, and the dunes appear to be moving slowly south-eastward. Approximately 5 per cent of these dunes are covered with shrubs. Vegetation cover increases towards two small lakes supplied by the Ruo Shui. Breed (1977) notes that the northern and western boundaries of the main dune field coincide with the 1220 m elevation contour, while the downwind eastern and southern boundaries largely coincide with the 1524 m elevation contour. Dunes averaging 200–300 metres in height, but occasionally more than 500 m high, are in the central and eastern Badain Jaran Desert (Zhu and others, 1980). These dunes may be the tallest sand dunes on Earth. They were mapped by Breed and others (1979) as star dunes with simple crescentic ridges. Although the dunes are very sparsely vegetated, they appear to be stable. The interdunal areas are filled with small dunes, marshes, or salt lakes fed by freshwater springs. The springs are sometimes referred to locally as desert pearls.

→ Dr Walker is a geologist at the United States Geological Survey, Reston, VA, USA; J. W. Olsen works in the Department of Anthropology at the University of Arizona and Bagen is a member of the College of Agriculture and Animal Husbandary, Nei Monggol, China. This paper was approved for publication in October 1986.

0016–7938/87/0002–205/$00.20/0

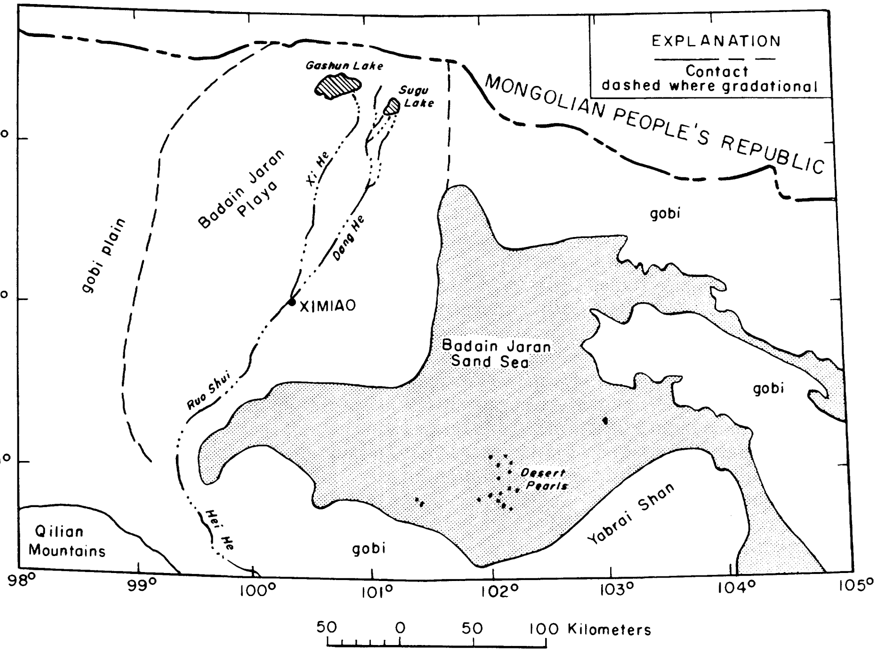


Fig. 1. Badain Jaran Desert area, after Lanzhou Institute of Desert Research (1979)

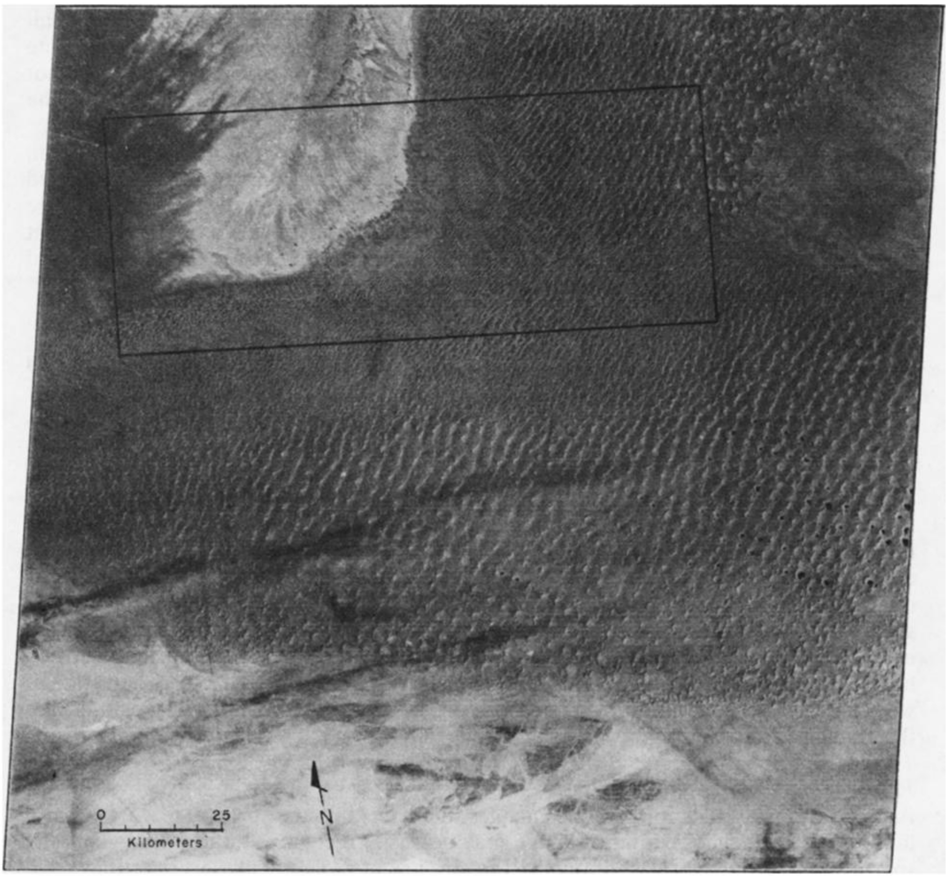
The north-western border of the sand sea is a playa that grades into a gobi plain. Gobi forms the south-west border of the sand sea. Contacts with the plain are gradational. Water from the Qilian Shan flows north into the Badain Jaran as the perennial stream Hei He. Down stream where the stream becomes ephemeral, its name changes to Ruo Shui. At Ximiao, uplifted sedimentary rocks split the Ruo Shui into the Dong He (East River) and the Xi He (West River). These ephemeral streams flow into Sugu Lake and Gashun Lake, respectively. Gashun Lake is presently dry.

Remote sensing data afford an excellent opportunity to analyze the geomorphology of the Badain Jaran Desert. The desert has been imaged by both Landsat and Shuttle Imaging Radar (SIR-A). Landsat is a passive system that records reflected radiation in the visible and near-infrared spectra, whereas radar is an active sensor that senses surface roughness and dielectrical properties. Characteristics of the desert produce different signatures on Landsat and SIR images which can be used synergistically to enhance the information available on each type of image.

Landsat

Plate I is a Landsat image of the western Badain Jaran Desert. The lakes and marshes in the bottom left of this image are in lines 3 kilometres apart running north-west to south-east. A second, less-developed linear pattern, also at 3 kilometre intervals, is perpendicular to the main trend. Walker (1982) has suggested that freshwater springs which feed to the lakes and marshes may be controlled by two groups of roughly parallel faults running south-east to north-west buried beneath the sand. If this is the case, previously unrecognized sources of potable water may exist along extensions of the faults. However, the lakes may simply occupy parts of interdune corridors between parallel dune ridges where the desert floor has been deflated to greater depths. It may be noted that Lou (1962) states that the lakes were more than 30 metres deeper at times during the Quaternary.

PLATE I



Landsat image of the western Badain Jaran Desert. The playa is on the upper left. SIR-A radar coverage is outlined. Image 2096–03161

Many of the crescentic ridges in this area also appear to be 3 kilometres long or to curve at 3 kilometre intervals, and most of them are also 3 kilometres apart. This suggests that the dunes are controlled not only by aeolian processes but also by the subsurface bedrock structure. Similar patterns occur in many other sand seas of the world with no structural control (Breed and others, 1979), however the arrangement of the springs in this desert suggests structural control. The exact nature of the relationship of the windblown sand to the underlying bedrock can be determined only by extensive field investigations.

Shuttle Imaging Radar (SIR-A)

The Shuttle Imaging Radar system was carried on board space shuttle missions in 1981 (SIR-A) and 1984 (SIR-B). Data Takes 7 and 28 of SIR-A covered parts of the Badain Jaran Desert. The SIR sensors are L-band (23.5 cm) horizontally polarized radar. The resolution of SIR-A is better than 40 m, and the contact scale of the image is 1:500 000. Plate II is a contact print of the Badain Jaran Desert from DT 7 of SIR-A. The area is outlined on Plate I, the Landsat image.

Dunes commonly have a dark response typical of smooth surfaces on radar unless the dunes have slipfaces oriented normal to the incident radar beam (Blom and Elachi, 1981). The Landsat image, Plate I, shows that slipfaces of these dunes are toward the south-east, and hence they are not normal to the radar beam. As discussed by Breed and others (1982), the mottled appearance of the dunes on the radar may be from small secondary slipfaces oriented to the south, normal to the radar beam. The true orientation and morphology of the dunes, easily visible on the Landsat image, cannot be determined with the radar image obtained from the aspect angle used during the SIR-A mission (Breed and others, 1982).

Guo and others (1985) mapped three patterns of radar return in the Badain Jaran sand sea. They noted a short curvilinear return pattern from slipfaces oriented toward the radar beam. Slipfaces not facing the beam have no return. Small bright patterns are returns from secondary dunes perpendicular to the radar beam, and circular bright return patterns are created near the rims of the interdunal lakes by the rough vegetated surface. These returns may be seen on Plate II.

Comparison of Landsat and SIR-A

The Badain Jaran Playa was imaged by both Landsat and SIR-A, which record different signatures for this surface. An abrupt change in wavelength of the dune pattern near the playa, perhaps caused by topography, is mappable on Landsat, but this change is not seen on the SIR-A image. The south-eastern part of the playa appears to be considerably larger on the SIR-A image than on the Landsat image, where the dunes appear to grade into sand sheets adjacent to the playa. The radar image reveals levels of the playa that are not easily seen on Landsat, probably because they are concealed by a thin cover of sand or alluvial deposits. These playa levels are represented by sharp tonal contrasts on the radar image. Subsurface caliche deposits have been seen on SIR-A images of other desert areas (McCauley and others, 1982). With SIR-A, we may be seeing similar shallow subsurface penetration of dry surficial sand, revealing a more extensive playa than is detectable on Landsat. However, this relation must be verified by field work. Guo and others (1985) have recently demonstrated SIR-A penetration of wind blown sand that thinly covers bedrock in parts of the gobi plains area north-east of the Badain Jaran sand sea.

Paleoclimatic changes of the desert

Ample evidence exists for climatic changes that have affected surficial features in arid lands where effects of climatic change may be easily recognized due to the generally sparse vegetation cover. Additionally, the absence of moisture preserves artifacts and biotic remains that can be used as proxy climate records. By correlating archaeological sequences in a given area with topographic features that record climate changes such as drainage patterns and lake levels, it is often possible to achieve a long-term perspective on the human response to changing climatic regimes.

The archaeology of the Badain Jaran Desert and the Ruo Shui Valley that forms its western boundary are known from only two sources. In the late 1920s and early 1930s members of the Sino-Swedish Expeditions made several trips up the Ruo Shui to the saline lakes. Although historic (mostly Han Dynasty) remains were found to be most abundant, Stone Age traces were also noted by the investigators, particularly on the northern shore of Sugu Lake and at the watering-spot of Shini-usu between the two lakes (Bergman, 1945 and Maringer, 1950). In the 1960s, a collection of Stone Age artifacts from the Badain Jaran Desert proper (near the caravanserai of Ailiketiebuke, about 50 km east of Figure 1) was analyzed by Chinese archaeologists. The assemblage contains specimens that are thought to be of Pleistocene Age. Although the bulk of the Ruo Shui materials appears to be of Neolithic Holocene affiliation, the distribution of many artifacts suggests the possibility of earlier Pleistocene occupation. Archaeological evidence thus suggests that the Ruo Shui Valley was the site of prehistoric human activity. SIR-A data suggest the playa south-east of the saline lakes was formerly a considerably larger inland lake.

Acknowledgements

We wish to thank Carol S. Breed and John F. McCauley of the United States

PLATE II

SIR-A Image of the western Badain Jaran Desert including the playa. The image is 50 km wide. The location is outlined in Plate I. The image is from Data Take 7

Geological Survey, and Guo Huadong of the Academia Sinica Institute of Remote Sensing Application, PRC, for helpful discussions and comments.

References

Bergman, F. 1945 Travels and archaeological field-work in Mongolia and Sinkiang: a diary of the years 1927–1934. In Gergman, F. and others (eds.) *History of the expedition in Asia, 1927–1935:* Sino-Swedish Expedition Publication 26, Stockholm, Statens Etnografiska Museum.

Blom, R. and Elachi, C. 1981 Spaceborne and airborne imaging radar observations of sand dunes. *Journal of Geophysical Research* **86:** 3061–73.

Breed, C. S. 1977 Terrestrial analogs of the Hellespontus Dunes, Mars: *Icarus* **30:** 326–40.

Breed, C. S., Fryberger, S. G., Andrews, S., McCauley, C., Lennartz, F., Gebel, D. and Horstman, K. 1979 Regional studies of sand seas, using Landsat (ERTS) imagery. In McKee, E. D. (ed.) *A study of global sand seas.* U.S.G.S. Professional Paper 1052: 305–97.

Breed, C. S., McCauley, J. F., Schaber, G. G., Walker, A. S. and Berlin, G. L. 1982 Dunes on SIR-A images. In Camino, J. B., and Elachi, C. (eds.) *Shuttle Imaging Radar-A (SIR-A) Experiment.* JPL Publication **82–77,** 4–52–4–87.

Guo, H. D., Schaber, G. G., Breed, C. S. and Lewis, A. J. 1985 SIR-A radar response from sand dunes and subsurface rocks of Alashan Plateau in north central China. In Guo Huadong, *Remote Sensing research report: Environmental Remote Sensing Applications Laboratory,* Oregon State University 55–78.

Lanzhou Institute of Desert Research, Academia Sinica 1979 *Map of the deserts of China.* Map Publishing Society, Beijing, scale 1:400 000, 1 sheet (in Chinese).

Lou, T. M. 1962 The origin of the desert between Minqin and Badain Jaran Temple, Gansu, and the problems of its reclamation and utilization. In Research on sand control, Communist China: *Sand Control Group of Academia Sinica, National Technical Information Service Pub.* JPRS–19993, 225–43.

McCauley, J. F., Schaber, G. G., Breed, C. S., Grolier, M. J., Haynes, C. V., Issawi, B., Elachi, C. and Blom, R. 1982 Subsurface valleys and geoarcheology of the Eastern Sahara revealed by shuttle radar. *Science* **218:** 1004–19.

Maringer, J. 1950 *Contribution to the prehistory of Mongolia.* Sino-Swedish Expedition Publication 34, Stockholm, Statens Etnografiska Museum.

Walker, A. S. 1982 Deserts of China: *American Scientist* **70:** 366–76.

Yu S. Z., Li B., Cai W. Q. and Tan J. N. 1962 A survey of the gobi of western Inner Mongolia and Badain Jaran Desert. In Research on sand control, Communist China: *Sand Control Group of Academia Sinica, National Technical Information Service Pub.* JPRS–19993, 244–76.

Zhu Z. D., Wu Z. and Liu S. 1980 *General introduction to China's deserts.* Science Publication House, Beijing, (in Chinese).