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A Study of Settlement Remains near the Qiemo Oasis in Northwestern China using Satellite Imagery and DEM

OGATA Noboru*, YU Zhiyong, ITO Toshio, SOHMA Hidehiro, IDETA Kazuhisa

Abstract: In this paper, we offer our study results about the location and structure of remains of ancient settlements in an arid region using satellite imagery and DEM. After our overview of the study area, namely the Qiemo (Cherchen) in the Tarim Basin, northwestern China, we examined the settlement remains over a desert area extending southwestward from the present town of Qiemo. A network of remains of irrigation canals, which take the shape of ridges, was observed both on the ground and on the satellite imagery. We made a reconstruction of the ancient irrigation network, and examined its geomorphological context. We also discovered an interesting coincidence of the canal remains and the subtle elevations observable in the SRTM DEM. In conclusion, we offer a hypothesis that a powerful flood eroded the settlement surface making the irrigation impossible, and caused the abandonment of the settlements.

Key words: Qiemo (Cherchen) Oasis, Tarim Basin, China, settlement ruins, irrigation canals, satellite imagery

1. Introduction

In this paper, we describe the topographical structure and its change of ancient settlements in an arid region. The study area is the region around the Qiemo Oasis located in the southeastern part of the Tarim Basin in northwestern China. In the process of our research, we stressed utilization of geographic data such as satellite imagery and DEM in reconstructing the historical landscape. The results presented in this paper are part of the research project “The study of typology of archaeological sites in the Tarim Basin during the Silk Road ages from the viewpoint of geographical locations” subsidized by the Ministry of Education of the Japanese Government (Sohma 2007).

We present here our reconstruction of a network of ancient irrigation canals produced by inspecting satellite imagery. We also integrate results obtained from field surveys and historical materials into our research. Through examination of the
terrain of the ancient settlements and the reconstructed pattern of canals, we concluded that, at some time during the historical ages, a significant change of the river condition occurred causing the abandonment of the settlement.

Since their declassification in 1995, CORONA satellite photographs (intelligence satellite photographs acquired in the 1960's by the United States) have been used in Japan in many studies within archaeology, historical geography, and related fields (Ogata 1998; Senda and Ogata 1999; Sohma 1999; Ogata 2000; Watanabe 2002; Ogata 2003). Although new-generation high-resolution satellite imagery has been available since 1999, earliness of operation of CORONA satellites provides advantages for some academic fields such as studies of long-term environmental changes (Bindschadler and Vornberger 1998). Archaeology and historical geography also find CORONA's usefulness since its imagery shows the situations of study areas before changes caused by development and urbanization after 1960's (Kennedy 1998). Representative geo-archaeological applications of CORONA images include Philip et al. (2002) and Ur (2003).

In the Chinese histories, there are descriptions of military settlements in the northwestern arid regions of China supervised by the central government. Recent studies of unearthed texts have produced interesting insights concerning agricultural development in these settlements in ancient times. However, it is still difficult to relate these findings to specific archaeological locations. Therefore, as for the chronology, we can only refer to ‘ancient settlements’ that were abandoned roughly several hundred years ago.

We made research trips to the Qiemo (Cherchen) area of China on August 17, 2005. During the research trip, we also visited the famous archaeological site of Miran from August 13 to 15, and then visited some sites near the Ruoqiang (Charkhlik) Oasis. On August 17, after viewing the ancient tomb (tomb No. 24 in graveyard No. 1), we were guided to the remains of ancient irrigation canals amid sandy desert extending southwestward from the Qiemo Oasis.

2. Study Area

2-1. Overview of the study area

The study area of our research is the Qiemo (Cherchen) Oasis and surrounding area located on the southeastern edge of the Tarim Basin, northwestern China (Figure 1). The Takla Makan Desert extends northward from the oasis. As for the climate in this area, according to the China Meteorological Data Sharing Service System, the average air temperature at Ruoqiang (Charkhlik) is 11.7°C while the
annual precipitation is 29.0 millimeters. The monthly mean temperature is 27.5°C in July and –7.4°C in January. As is usual in inland regions, the annual range of temperature is very large. The aridity index by Martonne, calculated from the annual mean temperature and the annual precipitation, is 1.3, indicating a very dry climate. Considering that the annual precipitation at Kucha on the northern edge of the Tarim Basin is 74.5 millimeters, the aridity is very severe on the southern edge of the basin.

The Qiemo Oasis extends over the dissected alluvial fan where Cherchen River flows from Altun Range into the Tarim Basin. In the oasis, the economy of settlement is based on agriculture using irrigation from Cherchen River. Compared with other rivers flowing into the southeastern edge of the basin such as Chalkhlik River and Miran River, Cherchen River has a large flow and provides water to a large area of the oasis.

2-2. Information from ancient Chinese historical records

Sima Qian, a Chinese historiographer of the Western Han period (2nd - 1st century BCE), described oases such as Loulan and Yutian (modern Hetian) in the western region of China in his history, *Shiji*. Ban Gu described in his history, *Hanshu*, that the Chinese Western Han government supervised military settlements near the kingdom of Shanshan (former Loulan) in the first century BCE. Ban Gu's description that the Qiemo kingdom was located in the west of Shanshan gives some supposition about the central oasis of the Shanshan kingdom.

Written in the period of the Northern and Southern dynasties, Song Yun's
record of his journey to India, included in Yang Xuanzhi’s book, *Luoyang Qielanji* (*A Record of Buddhist Monasteries in Luoyang*), describes the city of Zuomo; “This land was deficient in rainfall, so the people grew wheat by inundating their fields with water” (Yang trans. Wang 1984: 218). From this description, we can conclude that, in the 6th century, people cultivated crops in the oasis cultivation based on irrigation.

Also in the 6th century, Li Daoyuan, in his book on rivers, *Shuijingzhu*, set out the following story. Suo Mai, a military officer from Dunhuang, planned to settle one thousand soldiers from the western regions in ‘the Loulan kingdom.’ To create an irrigation system, he constructed a dam across ‘Zhubin River’ with great difficulty, and then succeeded to reclaim a large area for cultivated fields. Although this story seems to be fictional, we consider that it bears some relation to the military settlement in the Tarim Basin supervised by the Chinese government of the time. In his study, Ito (1999) associates this story with unearthed texts from that period concerning irrigation and agricultural activities.

Xuanzang, a Chinese Buddhist priest who traveled to India in the 7th century, mentioned “the ancient kingdom of Zhe-mo-tuo-na, which is the same as the country called Jumo (Qiemo)” in his book *Datang Xiyuji* (*Buddhist Records of the Western World*). Of Zhe-mo-tuo-na he wrote, “the city walls still stand loftily, but the inhabitants are dispersed and scattered” (Hiuen Tsiang trans. Beal 1884: 325). The name ‘Zhe-mo-tuo-na’ is considered a transliteration of the place name ‘Chalmadana’ in Kharosthi letters as found in unearthed texts from that region. Accounts of the southeastern part of the Tarim Basin faded from official histories of the Chinese dynasties.

### 2-3. Research in early modern times

N. M. Przhevalskii, a Russian military officer and pioneer explorer of the Silk Road region, visited Cherchen (Qiemo) in April 1885. According to his records, the oasis was settled by people from other oases in the Tarim Basin “about 90 years ago.” He also noted that settlement ruins extended near the oasis and the inhabitants used to collect treasures from old graves among the ruins. These graves might correspond to the Zaghunluk Cemetery Area described below.

A. Stein, the most prominent researcher of the Silk Road region in the early 20th century, stayed at Charchan (Qiemo) from November 21 to 22, 1906, and explored the ruins extending southwestward from the oasis. His observations made at the time are recorded in the research report *Serindia* (Stein 1921: 293-317). After he traversed deserted land for 3 miles, he saw remains of an irrigation
canal called ‘Yangi-üstang,’ which means ‘the new canal.’ This name was due to the settlers restoring the lower part of the ancient canal to reuse and reclaim cultivated land ‘some twenty years before.’

Stein observed the remains of ancient settlements extending along the ancient canal. These settlement remains were referred to as ‘kôhne-shahl,’ which means ruins, and were specifically called ‘Nân-yaigan Tati’ and ‘Lâlulik Tati.’ He had visited ‘Kakshal Tati’ near the Gûma Oasis (Pishan) on October 6, 1900, and had also been informed of similar ruins in the suburbs of Khotan (Hetian) which were also called ‘tati.’ Accordingly, he considered that the local word ‘tati’ referred to ruins of some specific sort. In *Ancient Khotan*, his academic report of the former research trip, he summarized the general characteristics of ‘tati’ as follows (Stein 1907: 103-109). (1) Unlike ruins such as Dandân-Uiliq, Niya and Endere, tatis lack significant structural remains. (2) Tatis exhibit much debris scattered on naturally piled loess. (3) Tatis exhibit more densely scattered debris on the top surfaces of ‘banks’ of 8 – 12 feet in height. The banks are yardang-like terraces with flat tops, which can be observed in the region. (4) Nether artifacts nor strata with remains of human activity can be found on the sides of the banks. Stein considered that the peculiar landscape of tatis had been caused by wind erosion.

3. Study method and geomorphological analysis

3-1. Case study of Miran site

After inspecting the Charchan (Qiemo) site, Stein advanced eastward, stopping at the Miran site on the way to the Loulan site. Here, he noticed several ridge-shaped remains of ancient irrigation canals. After surveying the Loulan site, he returned to the Miran site on January 24, 1907, and started surveying the site. A famous fresco depicting winged men and other finds were discovered in this survey. Remains, including those of a fort, a temple, stupas, beacons were recorded and numbered, and subsequently reported in *Serindia* with illustrations and plates.

In the middle of the 1980’s, Chen (1984) and Rao (1984) published studies on the remains of an irrigation network at the Milan (Miran) site. These papers include illustrations of the layout of the reconstructed network, although it is not mentioned whether the reconstructions depended on aerial photographs. The study subjects are pertinent to the present study, but compared to our study based on satellite photographs mentioned below, the geometry of their reconstruction of the network is not precise. Rao’s identification of the Miran site with a military settlement at Yixun mentioned in *Hanshu* seems to depend on poor reasoning.
Recently, Sohma (2003) used CORONA satellite photographs to examine the remains of irrigation canals stretching over the Miran site. The site extends over the upper surface of the dissected alluvial fan of Miran River, and the network of irrigation canals identified on the satellite photographs shows a dendritic pattern. The remains of irrigation canals are interpreted as linear ridges. This irrigation network is composed of a trunk line stemming from Miran River, branch lines (2nd order), and the terminal lines (3rd order) running like parallel stripes. The pattern of the network appears systematic in nature. Sohma’s study provides a guideline to the present case study of the Qiemo Oasis.

3-2. QuickBird satellite imagery

We used CORONA satellite photographs for our study because of their high resolution, earliness of acquisition, and availability of stereo pairs. However, because recently available QuickBird satellite images have a much higher resolution and quality than the CORONA satellite photographs, we also utilized these digital images. Since QuickBird images are expensive and the price depends on the size of the purchased area, we obtained a panchromatic image for an area of 8 (east-west) by 9 (north-south) kilometers that forms part of the study area. This image was acquired on February 8, 2006 (Figure 9). By inspecting this image, we concluded that it provides precise information about detailed features and topography.

3-3. Geomorphological analysis using SRTM data

We first analyzed the geomorphology of the study area using the stereoscopic view of CORONA satellite photographs and observed several surfaces of dissected alluvial fan of Cherchen River. However, because stereoscopic view does not provide quantitative metrics, we then used SRTM DEM data to model the geomorphology of the study area. Three arc-second interval grid elevation data were selected for a 30 arc-minute quadrangular area (about 43.7 by 55.6 kilometers) centered at 38 deg. 10 min. north, 85 deg. 30 min. east. Figure 2 shows this area and Figure 3 shows a bird’s eye view of the area. In Figure 3, the view is from the northeast and elevation is exaggerated 12-fold.

In Figure 2, which shows an overview of the study area, contour lines were drawn at elevation intervals of 25 meters from the SRTM data. LANDSAT TM false color image acquired on October 16, 1990 is also shown to depict the river courses and an extension of the oasis and desert. Because the study area is mostly covered
Figure 2: Overview of topography and land cover of the Qiemo Oasis

Data sources: Band 3, 4 and 5 of Landsat TM (1990/10/16) and SRTM DEM data. The contour lines are drawn in the intervals of 25 meters of elevation based on SRTM DEM data. Frame a denotes the scope of Figures 8 and 11, and frame b that of Figures 9 and 10.
Figure 3: Bird’s eye view of the study area (that of Figure 2) using SRTM DEM and Landsat image. The altitude of the surface is exaggerated 12-fold.

Figure 4: Remains of a trunk line of the irrigation canal network extending southwestward of the Qiemo Oasis: Photo taken at 20:03, August 17, 2005.

Figure 5: A piece of clay stuck on the bottom of the remains of an irrigation canal: Photo taken at 20:12, August 17, 2005.

Figure 6: ‘Tati’ landscape with scattered pieces of pottery extending southwestward of the Qiemo Oasis: Photo taken at 22:05, August 17, 2005.

Figure 7: Pieces of pottery scattered on a yardang-like terrace in the ‘tati’ landscape: Photo taken at 21:38, August 17, 2005.
by sandy desert with many dunes, contours cannot be drawn smoothly. The alluvial
fan generally slopes down to the north forming three dissected surfaces. We labeled
these surfaces from the highest to the lowest as surface I, II, and III. Surface III,
the lowest of the three, forms the riverbed, on which the oasis is located. In the
lower part of the alluvial fan, surfaces II and III converge, and the oasis extends
into surface II. Our research is focused on the settlement ruins extending over
surface II (circled in Figure 3) the altitude of which is several meters higher than
surface III.

SRTM DEM data have a horizontal resolution of 90 meters, which is relatively
low and, from our inspection, questionable in quality. These data are fatally
erroneous for some regions and, in many cases, include subtle systematic noise.
However, these data are useful because of a nominal vertical resolution of 1 meter.
As such, in the case where topographic maps of 1:50000 scale are available, contour
intervals should be 10 or 20 meters. This vertical resolution is considered useful for
identification of subtle features on a relatively flat topography such as our study
area. As with the study of Mesopotamian alluvial plain by Hritz and Wilkinson
(2005), we produced very interesting research results from analysis of the SRTM
DEM data for our study area.

4. Overview of our field survey

In our field survey of the Qiemo (Cherchen) area on August 17, 2005, we
visited an ancient tomb (grave No. 24 in cemetery No. 1) in a desert field of ancient
cemeteries (the Zaghunluk Cemetery Area) extending southeastward from the
oasis. Chinese archaeologists had previously surveyed cemetery No. 1 and reported
their results (Xinjiang Museum, Bazhou Administrative Office of Cultural Relics,
Qiemo Cultural Center 1998). In their report of the dig, they estimated that the
cemetery dates to approximately three thousand years ago using the radiocarbon
method. They also reported that the design of an unearthed wooden carving
depicting birds was classified as from the late Chunqiu period (665-590 BCE). The
excavated bodies and goods in grave No. 24 could be observed in situ.

After the visit to the grave, we were guided to the remains of an ancient
irrigation canal amid sandy desert extending southwestward from the Qiemo
Oasis. The canal remains form linear ridges with a U-shaped linear hollow at the
top (Figure 4). The width of the canal at the base was in excess of 20 meters, and
the linear hollow at the top was several meters wide. The linear hollow can be
considered to correspond to the canal bed where water flowed. We observed pieces
of clay stuck to the bed of the linear hollows, which appeared to have been used to
prevent leakage (Figure 5).

In the region of the site amid sandy desert, we observed yardang-like terraces that Stein called ‘banks.’ We also found a lot of pieces of earthenware of various colors and shapes. This debris was scattered extensively on the ground (Figure 6), but many pieces were also found on the tops of terraces (Figure 7). However, we observed little remains of buildings or other structures nearby. These characteristics of the landscape are partly considered to correspond to a ‘tati’ landscape, which Stein defined. In contrast to Stein’s description, we discovered some relics of human activity on the sides of the terraces.

This archaeological site is extremely extensive with unclear boundaries. It consists of widely scattered debris of earthenware and lacks significant remains of buildings. Therefore, the site has been called by various names specifying different places (Archaeological Group Subordinated to the Comprehensive Surveying Team of Taklamakan 1990). Recently, the name ‘Lai-li-le-ke’ site became generally used (The Office of General Antique Survey of XUAR & the Team of General Antique Survey of Bayingolin Mongol Autonomous Prefecture 1993), although to the best of our knowledge, there is no comprehensive published study of the site.

5. Reconstruction of irrigation canal networks of Southwestern Qiemo Ruins

5-1. Reconstruction using CORONA satellite photographs

We examined the traces of the irrigation canals using CORONA satellite photographs taken on October 21, 1964. To interpret the satellite photographs, we followed Sohma’s method adopted in his case study of the Miran site (Sohma 2003). By inspecting the photographs of the Qiemo site, we identified the remains of a network of irrigation canals. The remains of these irrigation canals form linear ridges. The network as a whole shows a dendritic pattern and was spread over the surface II of the dissected alluvial fan.

As is the case at the Miran site, the fact that the irrigation canal remains are ridge-shaped might be explained by the original irrigation canals being constructed at an elevated position. Irrigation canals connected to rivers were constructed as linear ridges to facilitate water supply by natural flow without dependence on pumping.

The most striking features are several prominent trunk lines, which run through the site for several kilometers. The remains of irrigation canals, which we observed during the research trip in 2005, appear to be one of these trunk lines.
Figure 8: CORONA satellite photograph (1964/10/21) over the study area with reconstructed irrigation canals (black lines) extending over the middle altitude terrace. Irrigation canals under use at the time of photographing are depicted by white broken lines.
Figure 9: QuickBird satellite image (2006/02/08) over the study area near the Qiemu Oasis and area of the survey explored in August 2005.
Figure 10: Reconstructed system of irrigation canals based on inspection of the QuickBird satellite image (Figure 9).
In Figure 8, we show the remains of the identified irrigation network overlaid on the CORONA satellite photograph. Individual canal remains are classified into trunk lines, branch lines, and terminal lines, which can be distinguished by their width. This proposed method of watering should be possible under the condition of an alluvial fan in which slopes are relatively uniform. However, the upper parts of the trunk canals are poorly defined so that the points of water intake were not clear on the CORONA photographs.

5-2. Reconstruction using QuickBird satellite image

In the next step, on the basis of the reconstruction shown in Figure 8 and the ground observation, we performed a reconstruction using a QuickBird satellite image acquired on February 8, 2006 (Figure 9). Figure 10 shows our proposed irrigation network reconstructed from the QuickBird image.

By examining the image, we distinguished three trunk canals based on their widths. These trunk canals appear to have their sources at the upper reaches of Cherchen River. In the southeastern part of the QuickBird image, the upper parts of the trunk lines are often broken by dissection rills and sand dunes. In this part of the QuickBird image, we can observe that remains of several trunk canals run parallel to each other. To explain this observation, we propose several hypotheses. One possibility is that two or more trunk canals were used simultaneously to supply water to separate irrigation systems. Another possibility is that one trunk canal replaced another. These hypotheses remain to be examined. Parallel remains of trunk canals can also be observed in the lower part. It appears that these features relate to the replacement of one component of the irrigation system by another through repair.

We also observe an unusual feature in that the northern trunk canal and the middle one converge at the lower part (near the northwestern corner of the image). These two trunk canals can be considered to have been used complementarily to feed water to the northwestern area, which is currently cultivated.

As for the branch and terminal canals, two key points should be noted. (1) The observed distribution of these lower-order canals is uneven. (2) The observed patterns of the terminal canals are less regular than those of the Miran site. As for point (1), the distribution of the lower order canals might be interpreted as reflecting the extent of cultivated fields in the past. However, considering the arid conditions in which sand dunes migrate and wind erosion is significant, this unevenness can also be interpreted as reflecting the prevailing environmental conditions. We also speculate that the area of cultivated fields differed in different
Figure 11: Distribution of the surface elevation shown in grayscale and remains of irrigation canals (white lines) identified by inspecting the CORONA satellite photograph (Figure 8). The circle denotes the area where no canal remain was observed on the CORONA satellite photograph.
periods throughout the long history of settlement of the oasis.

5-3. Impact of irrigation on geomorphology

As mentioned above, traces of irrigation systems extend over the middle surface (surface II) of the dissected alluvial fan. From the geomorphological viewpoint, we can observe that developed rills transect the traces of the trunk canals. These phenomena are particularly apparent along the eastern boundary of surface II adjacent to surface III. These facts indicate the temporal order of construction of the irrigation systems and the development of the dissected rills, suggesting that the settlements over surface II and their abandonment occurred several hundreds years ago, although a specific date cannot be determined.

In the circled area in Figure 3, we can observe linear subtle elevations, which collectively form a dendritic pattern. Figure 11 shows the remains of irrigation canals identified in the CORONA photograph (the same as those in Figure 8) overlaid on shading corresponding to surface elevation. We can observe that the canal runs along the centers of the subtle linear elevations. These two features correspond very well. In the circled area in the Figure 11, where a fan-shaped subtle elevation can be observed, there are no canal remains identified on the CORONA photograph. However, in this area, the QuickBird image (Figure 10) shows thin canal remains radiating to form a sector.

The correspondence between subtle linear elevations and canal remains is considered as follows. We observed the remains of irrigation canals in our field survey and found that the original irrigation canals were constructed at elevated position to facilitate watering. Irrigation over hundreds of years might transport soils into the watered fields near the canals and cause the formation of subtle linear elevations. Another possibility is pointed out as follows. Irrigation canals that take form of linear ridges may trap shifting sand to shape the subtle linear elevations.

Hritz and Wilkinson (2006) examined the process of formation of subtle levees caused by irrigation activity. The results of our study provide further insight in the relationships between irrigation and subtle geomorphology on alluvial plains. Since the nature of this relationship depends on geographical conditions and on the age and nature of the irrigation system, comparative studies of various regions and times is an interesting research subject for the future.

5-4. Yangi-üstang — the new canal

In this section, we examine why the remains of an ancient canal were named ‘Yangi-üstang’ — ‘the new canal’ in the local language as recorded by Stein. Tan
(1999) pointed out that according to a local Chinese geography, the new canal was constructed in 1904 and the name ‘Ying-wu-si-tang’ was adopted as the village name. However, this description is inconsistent with Stein’s remark that ‘Yangi-üstang’ had been constructed about 20 years before his visit to Charchan (Qiemo) in 1906. Tan considered the possibility that the canal, which was constructed in 1904, is in fact another canal called ‘E-er-ke-ai-ri-ke.’

Stein’s Serindia has an appendix containing a series of maps. On the ‘Charchan’ sheet, we find a symbol of an irrigation canal running from south to north in the west of the Qiemo oasis. The symbol of the canal is labeled ‘ancient canal’ in the upper reaches (south) where the settlement ruins extend, but is labeled ‘restored canal’ in the lower reaches (north). The remains of the trunk canal mentioned above enter the existing (at the time the CORONA satellite photograph was taken in 1964) cultivated land. By examining the CORONA photograph, a modern irrigation canal is observed to stem from Cherchen river at the south of Cherchen City. It takes a roundabout route avoiding the height of surface II, and supply water westward from the oasis. We show these modern canal routes as broken white lines in Figure 8.

Stein and China’s local geography both mention the story that new settlers reused ancient remains of irrigation canals. We might hypothesize that these restored canals were provided with water from the newly constructed canal stemming from Cherchen River and drawn westward. We cannot associate ‘Yangi-üstang’ with modern canals identified on the CORONA photo. However, observing that surface III covers surface II in the northern part of the dissected alluvial fan, new fields might have been reclaimed on the deserted land for cultivation by reusing ancient canals that directed water westward.

6. Discussion

We have studied an archaeological site composed mainly of remains of irrigation canal systems, which extends in the southwest of the Qiemo Oasis. Although this site is larger than that of Miran, some unexplained findings were made. The remains of irrigation canals are often disconnected and stretches of lower-order canal networks are uneven in distribution. These features might be related to the process of development, maintenance, and abandonment of settlements and irrigation systems throughout the history of human inhabitation, although further detailed investigation is required.

One possible hypothesis is as follows. Settlements of the Qiemo Oasis once extended across the surface II of the alluvial fan of Cherchen River. Some time
after the earlier settlement, a powerful flood eroded the surface of the fan (surface II) to form a new riverbed (surface III). Therefore, the supply of water to surface II became difficult, so the settlements were abandoned. This catastrophe can be considered to have occurred hundreds years ago since naturally developed rills transect the trunk canal remains in the upper reaches (southeastern part of the area of Figure 10).

In modern times (according to Przhevalskii’s report in the 19th century), resettlement of the area occurred. Irrigation canals were constructed to supply water westward from the oasis, but ancient canal remains were also reused. Satellite images include detailed and useful information about remains of irrigation canals. However, it was difficult to identify the remains of cultivated fields and dwelling sites on the satellite images. Therefore, we had to refer to the ground surveys.

The purpose of our research in a broad sense was to characterize the relationship between environmental change and human developments and settlements. In this article, we believe that we obtained new insight into the relationship between change in the conditions of Cherchen River and the development and abandonment of settlements in the Qiemo Oasis. We made remarkable discovery that cultivation based on sophisticated and extensive irrigation systems, which lasted for long period, resulted in change in the geomorphology, namely, the dendritic-shaped subtle linear elevations. On the other hand, geomorphological change caused by fluvial activity, namely, dissection of the alluvial fan and formation of surface III resulted in abandonment of the settlement. Possible future research includes more cohesive combination of interpretation of satellite imagery with historical records and archaeological findings.

T. J. Wilkinson, who joined a group researching Middle Eastern archaeology in northeastern Syria, utilized aerial photographs and CORONA photographs to study artificial geomorphological features (Wilkinson 2001). In his recently published book, he proposed a landscape archaeological framework for studying Middle Eastern archaeology (Wilkinson 2003). In contrast with conventional archaeology, which tends to focus on archaeological sites and unearthed artifacts, Wilkinson stressed the importance of considering archaeological sites in the context of landscape or environment in line with the tradition of landscape archaeology from Europe (Aston 1985). He adopted a methodology involving the development of a typology of landscape elements such as settlements that take the form of tells, water-supply systems, arable fields, agricultural installations, roads, and so on. This typology makes up an important component of his methodology.
While Wilkinson’s research is an approach from the field of archaeology, his framework can be considered to be inspired by geography in respects to the relationship between environment and human activity and the utilization of geographic information technologies. Since many studies of ancient landscapes have been undertaken in Japan and East Asia and other regions, the framework of typology of landscape elements peculiar to regions under study should be established. Therefore, in the future, we should aim to establish different frameworks of landscape research for different times and regions in the world.

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[後記] 本稿の元になった原稿は，相馬先生も執筆に参加して2009年に作成された。学術雑誌に投稿したが，掲載には至らなかった。本稿で参照された文献など，研究状況に関しては，2009年の原稿作成当時のものである。相馬先生の斬新な着眼点に立脚した有意義で興味深い内容を含むにもかかわらず，今まで刊行の機会を持てなかったのは，筆頭著者である私の非力と怠慢による。ここに深くお詫びするとともに，あらためて相馬先生のご冥福をお祈り申し上げます。

小方記す。