# A 5000-Years History of Settlement and Irrigation in the Murghab Delta (Turkmenistan).

## An Attempt of Reconstruction of Ancient Deltaic System

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*Abstract: The present paper introduces the main problem of the water lack in the Murghab delta during the ancient time and the fundamental position occupied by GIS applications and Image Processing for the reconstruction of the ancient irrigation system. A vast collection of data has been gathered and organised in a Geographical Information System to prepare thematic mapping and 3-D visualisation, illustrating the settlement and the environmental history of the Murghab delta from 3000 BC to the Achaemenid period (550-300? BC).*

*One of the final aims of the research is to realise a Multidimensional Geographical Information System, capable of representing the dynamics of the evolution of such a complex and multitemporal-layer reconstruction of a large-scale model of geoarchaeological landscape in Central Asia*

*Key words: Turkmenistan – Murghab – River - Geographical Information System - Digital Elevation Model*

The alluvial lowlands of Asia have long been recognised the heartland of early civilisation, expressed by high concentrations of settlements and agriculture production. The early states and the pristine agencies of political complexity developed in these vast open corridors from the economic wealth that grew throughout Chalcolithic times within the villages and kinship structure, born by the Neolithic Revolution. The first cities, where the outputs of the second leap forward in political evolution, made the social and economic breakdown of the earlier agriculture communities.

By 1966 the New Archaeology Movement advocated the priority of settlement studies for the understanding of the social and economic history (Binford, Binford 1968). The study of the human settlement provided new powerful means to read the historical fluctuation on man-made landscape (Chang 1972). The systematic study of ancient settlement in the cartographic definition was based on thematic maps, seriated according to chronological periods. Archaeological maps became an essential product to establish the quality of archaeological projects, creating a widespread demand for high definition analysis of special distribution and hierarchical rending of human settlement. The authors of the first chronological thematic maps, based on the study of ancient settlements, were Gordon R. Willey (Willey 1953) in the Virù valley in Peru and Robert Mc C. Adams (Adams 1981), working in the Diyala region in Iraq. Personal computers and specific software changed the methodology of archaeological research since the American and European specialists requested more complex elaboration and representations.

The main problem concerning the big rivers of Central Asia is the lack of sea way out (fig. 1). The deltaic branches flow across the Kara-Kum desert and the hyperarid climate causes the evaporation and the underground infiltration of the river water. In the Murghab delta the terminal lake of Dzhar, located on the north-westernmost part of the system, represents the only collecting point of the river water as represented by the Russian topographical military map[1] (fig. 2). On the '800 map (Lumsden 1885) (fig. 3) the Aina-gel, the present fossil lake on the western side of Dzhar on the 1995 maps, represents the second collecting point of Murghab water. Merv and the alluvial plain of the Murghab delta have been massively destroyed for extensive land reclaims and irrigation works from the Kara-Kum Kanal, feeding in the area the Amu-darya waters. In face of the rapid deterioration, the authorities of Turkmenistan have invited foreign projects to document the antiquities of the delta. The joint project "The Archaeological Map of the Murghab Delta (AMMD)" initiated in 1990 as a co-operative effort of Italian, Russian and Turkmen specialists[2]. A large spectrum of specialists and technicians of different nationalities and skills created a vast archive of data by intensive ground reconnaissance, low altitude flights and by adopting state-of-the-art technologies for image processing and field.

In order to preserve this unique aspect of cultural heritage of Turkmenistan, a lot of work still needs to be done in spite of the intensive research carried out in the past ten years. The urgency for the project was mainly dictated by the looming destruction of the sites for the expansion of cultivation in the northern part of the Murghab delta. Considered the more intensive series of field observations, we organized and administered the enormous quantity of cartographic and archive data so far collected by entrusting them to an interactive system like Geographic Infor-

mation System (GIS). The GIS has been used like an instrument to assemble and manage the vast arrays of diversified archives to be merged in a historical analyses of settlement and population. Satellite imagery and the digitalisation of aerial photographs in general are providing another mean for the definition of ancient landscape, before and beyond direct fields of observation. Only recently, this new important instrument has been applied to a large-scale analysis in the alluvial plains of the Middle East and Central Asia.

In addition to the historical and archaeological data of Turkmenistan, the satellite survey of the region has enabled the use of new analytical methods. This type of supports is used on large scale in the archaeological project to define the ancient landscape (Gardin, Gentelle 1976; Adams 1981; Forte, Mozzi, Zocchi 1998). We therefore have directed our research towards the interpretation of the digital and cartographic data on a geoarchaeological basis. It is especially interesting in this case by using the comparison of the geomorphological landscape (fig. 4) and the situation of the ancient sites, taking the Digital Elevation Model (DEM) imagery as a background (fig. 5). The DEM is the digital representation of continuous changes of relief within space (Burrough 1986: 39; Gaffney, Stanchich 1996: 23) and any elevation variation in the territory of delta may be a trace of a palaeochannel presence. V. Castellani maintains that the irrigation system of delta has certainly changed[3]. The river cut across the plateau and left a detritus conoid, depositing again in the same cut and flowing through its deposits. It suggests the remarkable shrinkage of water supply, and the absence of river grid on aerial photographs confirms the low rain level of the delta in the past. Probably the ancient settlements stocked up the water directly from the river channels, confirming the reason of archaeological site location along the palaeochannels. In the second time the growing climate aridity and the spring dryness drastically transformed the landscape and the settlement pattern over the territory.

Considering the available information, we prepared a Vectorial Cartographic Digitalisation of historical maps on different layers. The main aim is to reconstruct the ancient irrigation system before the building of Kara-Kum canal and to obtain the original river for understanding the historical process determining the present delta. This is fundamental for a comprehension of settlement pattern distribution of archaeological sites, during the different chronological periods, into the ancient landscape. A careful analysis of topographical, geographical, historical, environmental and geological maps permitted to reconstruct the water supply history of Murghab river from late Chalcolithic to Achaemenid period.

The GIS software used in the application ArcView 3.2 allows many different data in thematic maps and complex spatial analyses, integrating information from infinite levels of subdivision recording. The transformation of archaeological map of the Murghab Delta into the GIS has presented various levels of difficulty (Cerasetti in press). The principle problem derives from the large size and high diversification of the data to be organized.

The first application of the GIS is concerning the thematic mapping of the site discoveries according to chronology and size. The set of graphs has been produced as well to provide a first level of representation for the change of population distribution (fig. 6). Massive alluvial sedimentation has buried the earliest settlement history of the Murghab lowlands. The stability of the Murghab delta has left little opportunities to detect from the surface all the Neolithic and Chalcolithic sites. In general from the middle Bronze Age onward the surface evidence represents a reliable reading-key of the archaeological situation and the data coming from the survey may be utilised with minimal constraints. As Italian specialists have well evidenced from pedological analysis and geomorphological observation, the early and middle Bronze Age original plain was contracted and cut across by the southward movement of aeolian sands that determined a chromatic change in settlement pattern. The regularly patterned settlement distribution of the early Bronze Age fertile plain changed into clusters of small oases aligned along the active watercourses (fig. 7). The relative map shows the sites of this period with the main centres located at Gonur North and Adzi Kui 8, developed in close connection with a main deltaic canal, feeding a network of natural and artificial water-courses (fig. 8). During the late Bronze Age period we record a sharp increase of the site number across the whole alluvial plain and the southwards expansion of the settlement distribution. In the following periods the settlement pattern is more coherent and the process of consolidation of a state organization is definitive. The ancient Margiana has become a region of far greater and more complex political system.

As I. Rouse said (Rouse 1972: 1), the archaeological record spatial distribution testifies the cultural and social human activities and the relations among ecological, cultural and social systems It is fundamental to understand the adaptation process into a surrounding landscape and the exploitation of available natural sources. In our case the methods of river water exploitation represent the reading key to understand every settled phenomena during Bronze and Iron Age. The site distribution maps confirm the subservience from the main water-courses from 2400 to 300 BC. The site location along the palaeochannels and the archaeological surface material allowed us to date the main water-courses inside the relative irrigation systems.

One of the main aims of our research concerns the chronological sequence reconstruction of the main irrigation systems, elaborating the data of the river morphological evolution by means a GIS application. The global visualization of the settlement pattern from middle Bronze Age to late Iron Age, connecting to the ancient deltaic systems allowed us to know the waterworks adopted in different periods for the settlement subsistence. We have reconstructed the three main systems Dzhar lake, Murghab river and Sultan-ab systems[4] (fig. 9), working approximately at the same time from the end of IV to the end of I millennium BC. The river water exploitation is a no-artificial process till Achaemenid period , characterized by the construction of the main dams. A detailed surface recognition of the area surrounding the great dams as Great Band and Sultan Band, located along the main streams of Murghab could make us able to understand better the river supply projects during the well documented historical times: these enormous waterworks were certainly supported by a central power, very well organized and capable to face the incessant problem of

river regression. Mainly for this reason we dated at this period the great dams: the consolidation of central power allows economical sources to erect this type of public structures. The construction and the regular maintenance of the channels entail a great human energy employment and the surviving depends on a complex administrative and executive system. More arduous is the attempt of the main irrigation system reconstruction during the pre-historical times, considering the absence of direct sources and artificial structures. In this case the Geographical Information System has been fundamental.

At the end of IV and the beginning of III millennium BC the portion of territory between two sub-deltas of Aravalli and Merv oasis was probably occupied by alluvial swamp of Dzhar lake, 82 kilometres north-extending (fig. 10). The area is completely lacking in archaeological surface material and the middle Bronze and Iron Age sites are located along natural palaeochannel, bordering the east side of the alluvial swamp. The Dzhar lake and the surrounding landscape represented the highly important source of food, as fishes and birds, and fresh water. The Russian definition of *Dzhar*, the Persian *Jar*, means "verdant area, grassland", suggesting the lake as vital source in the ancient time and it is strictly linked with Murghab or *Morq-ab* definition (bird water), emphasizing the fundamental importance of the Murghab system[5]. The relative chronological thematic maps show that the region bordering the Dzhar alluvial swamp has been populated till the half of I millennium BC, characterized by a progressive regression of the settled area border.

The conformation and the chronology of the systems are identified according to the site distribution along the palaeochannels (fig. 11). The position of the main sites reinforces our hypothesis: the middle Bronze Age site of Gonur North is located along the same channel 2 of the final Bronze Age site of Takhirbaj 3, remaining the main water-course till the end of early Iron Age (fig. 12). The channel sides are settled less intensively during the second and the third phase of Iron Age, stopping its activity during the last phase. The water flow is going down and only 3 hectares sites last during late Bronze Age. Takhirbaj 3 is located at 20 kilometres distance from the main middle Bronze Age centre and it is gaining control over the territory during final Bronze Age. It means that during 600 years the river flow is considerably regressed and a regulating plan of the river water becomes urgent. At the beginning of the Iron Age the water decrease of channel 2 causes the advantage of channel 3 and the increasing of settlement distribution along its sides. During the second and the third phase of the Iron Age the channel 2 is practically abandoned and the channel 3 takes the upper hand, intensively exploited till the last phase. Differently from the first hypothesis[6] we suggest that the beginning of Sultan-ab system exploitation starts during the first phase of the Iron Age, confirmed by the GIS application. The main channels of Dzhar and Murghab river systems[7] are working at the same time from the middle Bronze Age to the third phase of the Iron Age: probably the intensive flow water allowed two systems working for a long time.

During the last phase of the Iron Age, with a consolidation of Achaemenid central power two impressive fortress lines were erected along the northern-eastern side of the Murghab delta (Genito 1998: 125, fig. 1) (fig. 13). Our hypothesis is that the defensive structures mainly guarded the Sultan-ab and Dzhar irrigation systems: the water lack must be the main problem for the subsistence during a period characterized by a remarkable increase of population. The problem of water sources forced enemies to try taking the control of the main courses of the Murghab river for a territorial control of the Margiana region. The more advanced line probably defended the Sultan-ab system, while the second line guarded the Dzhar lake system and Yaz-depe, the main centre of the region during the last phase of the Iron Age.

In our experiments of 3D analysis and visualization of the vectorial and raster data, we have exploited for the first time the potentialities of the software ER Mapper 6.1, realizing a 3-D model of the Murghab delta. It has been possible to visualize also different elaboration of the DEM on different colour types, producing a 3-D multilayer projection to obtain a virtual landscape as real as possible.

This multidisciplinary project implements advanced elaboration techniques both for multispectral images and for multitemporal-layer reconstruction of a large-scale model of geoarchaeological landscape in Central Asia. Soyuz KFA 1000 and ERTS-1 have been used in the first time to point out the beginning process of desertification. The ERTS, taken on 1972 only 30 years later the construction of Kara-Kum canal, testifies the regression step of the Murghab delta and the present irrigation areas (fig. 14). The CORONA 1961-1974 satellite imagery have disclosed new possibilities for the interpretation from the thematic mapping, since the major destruction of sites proceeds because of large-scale irrigation projects (fig. 15). It will also facilitate a spatial analysis between the evolution of the archaeological landscapes and the geomorphological characters of the region around Merv, opening new perspectives of research analysis in Southern Turkmenistan. In a second time we will add and overlap infinite information layers to the 3-D model and we expect that simulation will be able to advance on new pathways of higher complexity. We are still far from an exhaustive analysis of the data, but we are moving the first steps towards multimedia and 3-D publication of the elaborated data. The evolution and the integration of present applications in the GIS might represent a significant step for realizing a new 3-D addition of the digital archaeological map of Turkmenistan, containing consistent reconstruction of the ancient population.

## End notes

[1] The cartographic base map of Geographical Information System of Murghab delta is represented by a mosaic of fourteen 1:100,000 topographical military maps, dated on 1995 allowed us by *Turkmenskoe Aerogeodjicheskoe Predpriyatie* of Ashgabat.

[2] The Scientific Directors of the Project are: Prof G.A. Koshelenko, Director of the Section for Classical Archaeology of the Institute of Archaeology of Russian Academy of Sciences (IARAN) in Moscow; Prof A.G. Gubaev, Dean of Faculty of Oriental Studies of State University of Turkmenistan (TSU); Prof M. Tosi, Scientific Supervisor of AMMD of Italian Institute for Africa and Orient; Prof B. Genito, Istituto Universitario Orientale of Naples.

[3] The hypothesis is a part of not published preliminary work on Murghab delta.
[4] The name of the systems are arbitrary.
[5] The translation of Persian terms of *Jar* and *Morq-ab* is a personal communication of M. Sajjadi.
[6] M. Tosi suggested that the Sultan-ab system exploitation started during the third phase of the Iron Age.
[7] The Murghab river system originated the Merv oasis delta.

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## Figures

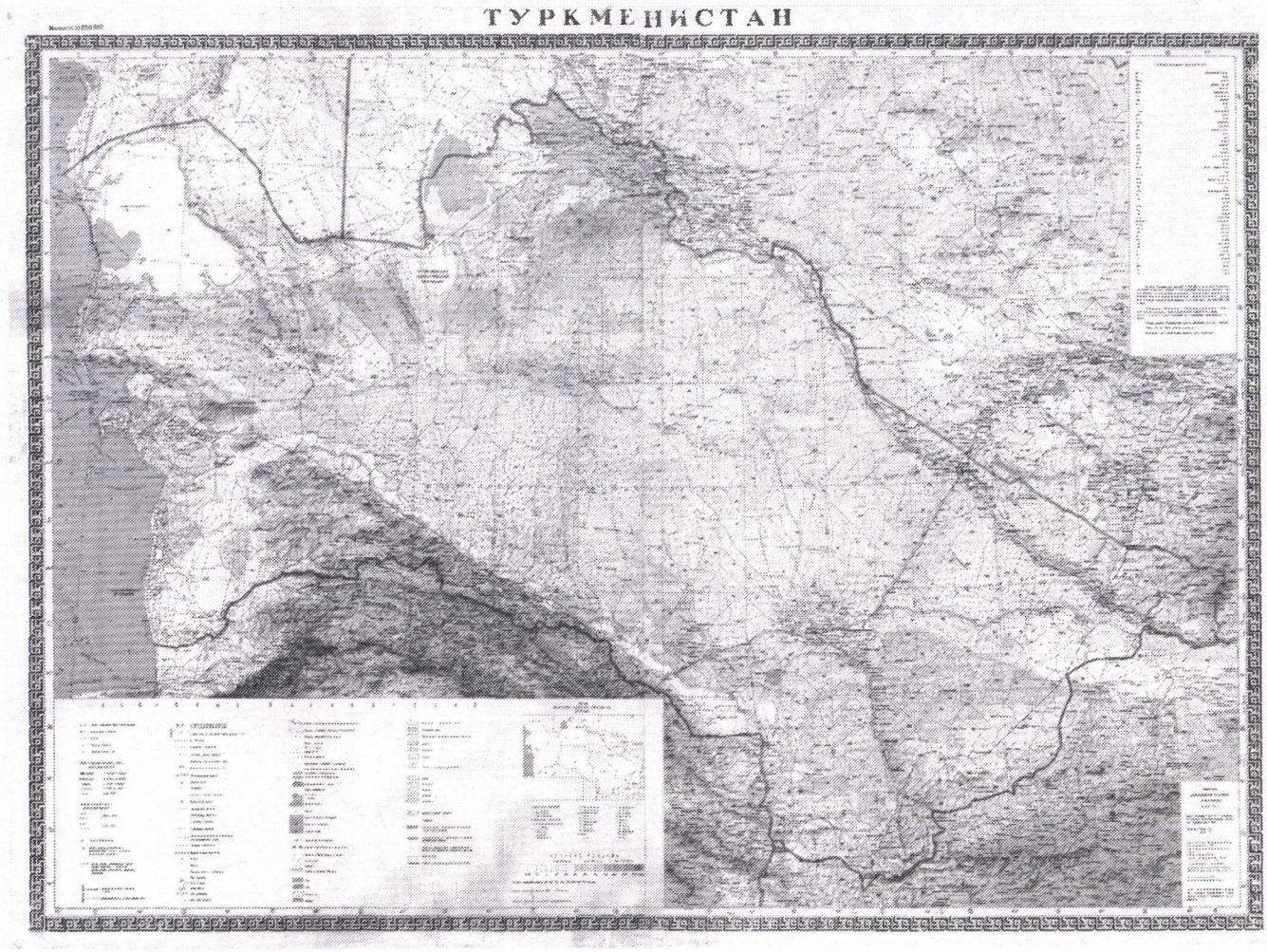


*Figure 1. Map of Turkmenistan*

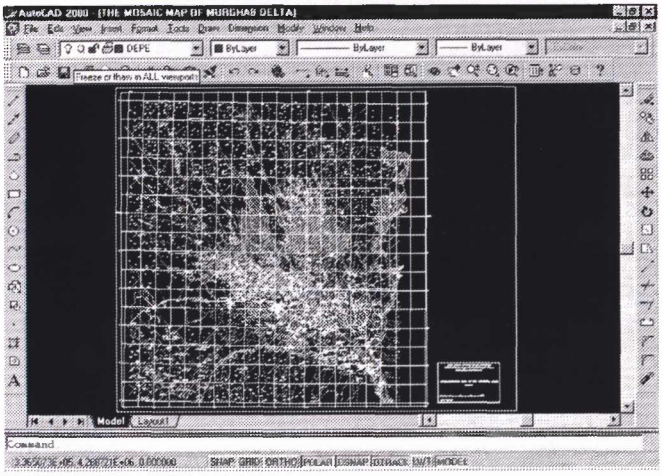


*Figure 2. 1:100,1000 Map Mosaic: the Cartographic Base of Murghab Delta GIS*

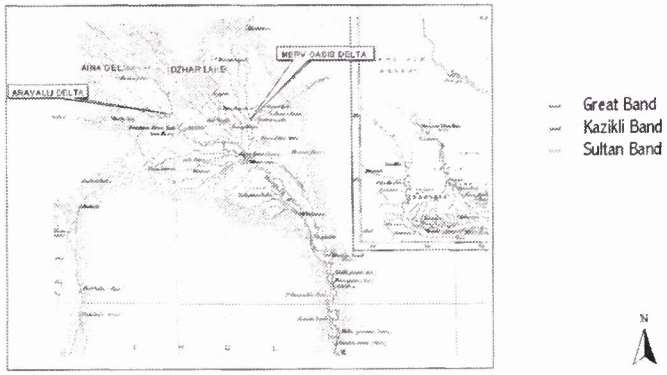


*Figure 3. Map of Major-General Sir Peter Lumsden 1885*

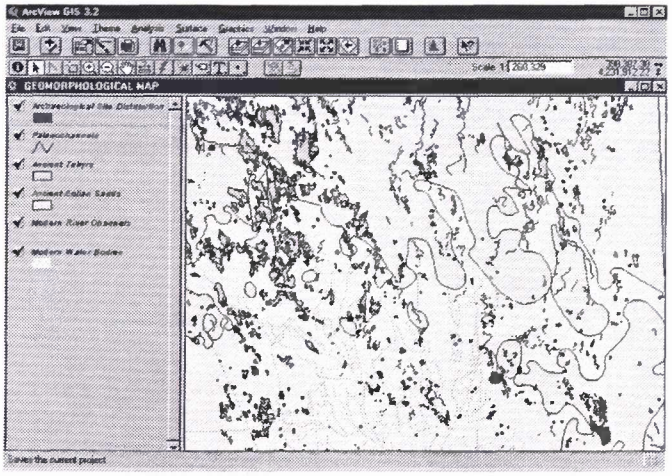


*Figure 4. Geomorphological Map of Merv Oasis Delta*

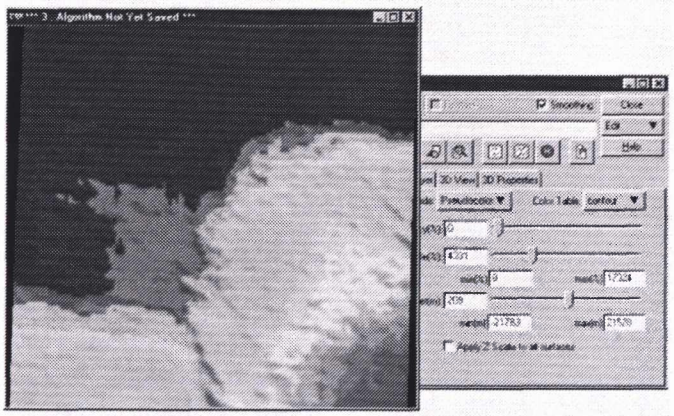

*Figure 5. Digital Elevation Model of Murghab Delta: an Application of ER Mapper 6.1*

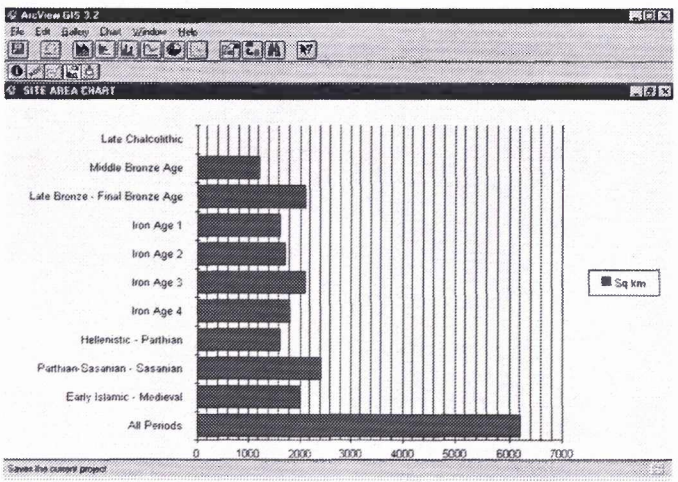


*Figure 6. Classification of Settlement Size by Period*

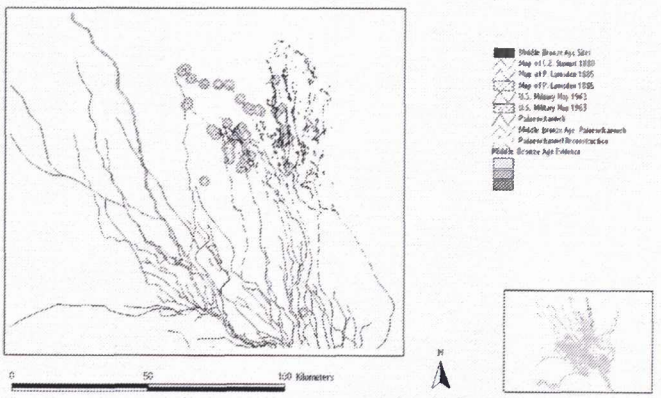

*Figure 7. Middle Bronze Age Site Area Distribution*

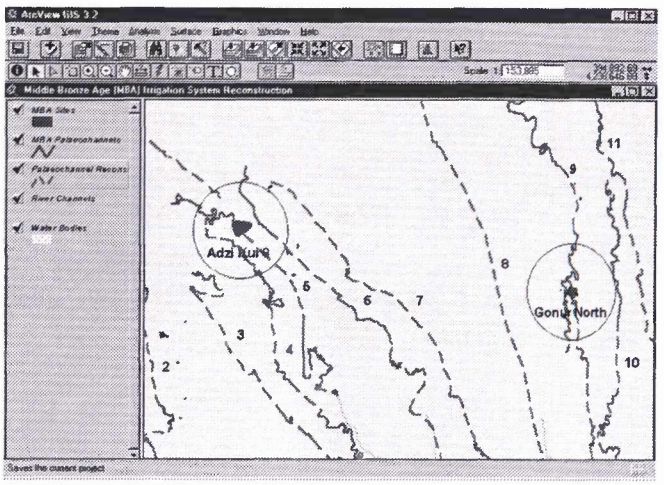


*Figure 8. The Main Sites of the Middle Bronze Age*

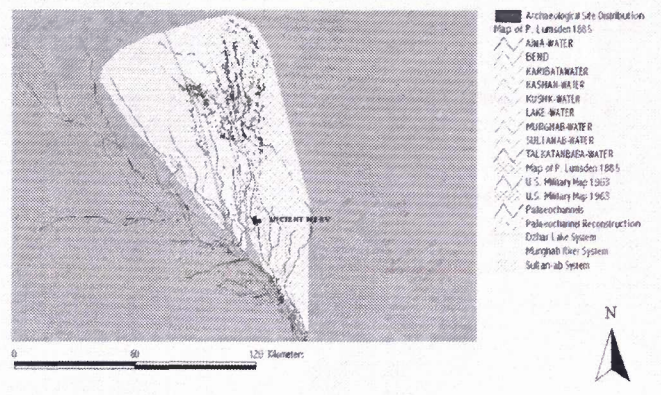


*Figure 9. Main Irrigation Systems: Dzhar Lake, Murghab River, Sultan-ab*

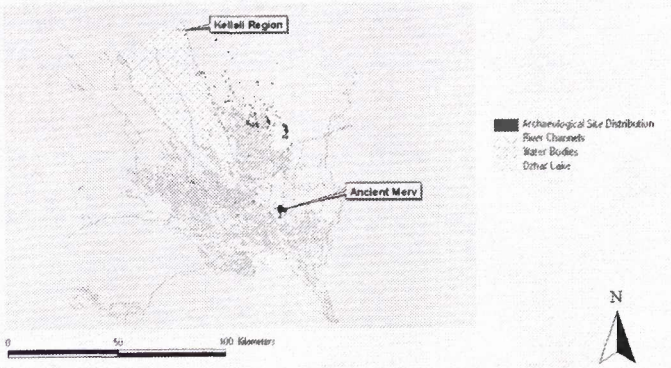


*Figure 10. The Kelleli Region in relation of the Dzhar Lake*

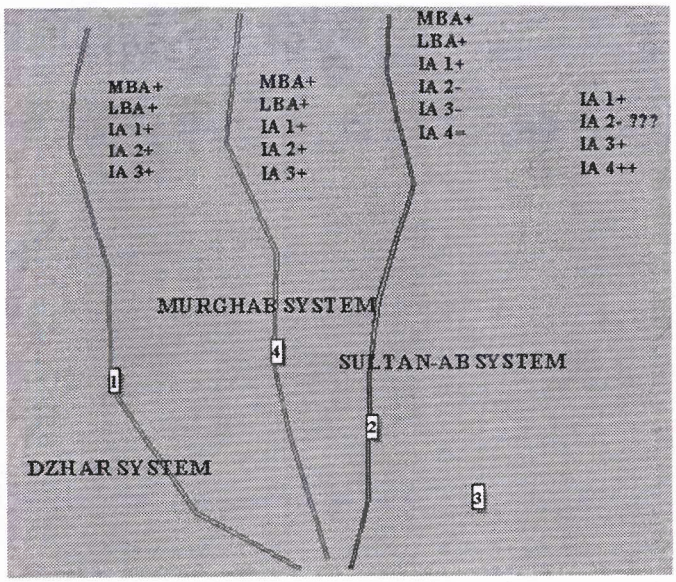


*Figure 11. Chronological Sequence of Main Irrigation Systems*

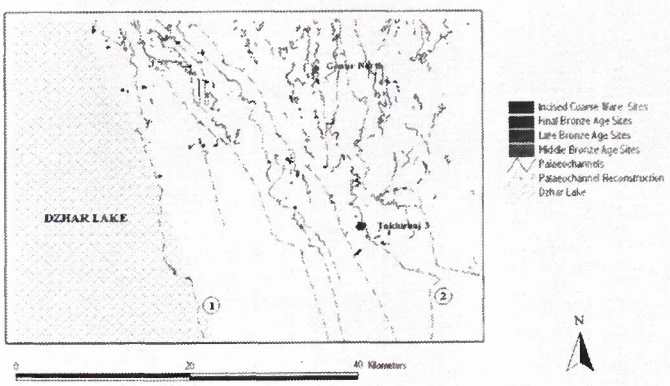


*Figure 12. The Irrigation Systems of Dzhar Lake and Sultan-ab: the Sites of Gonur North and Takhirbaj 3*

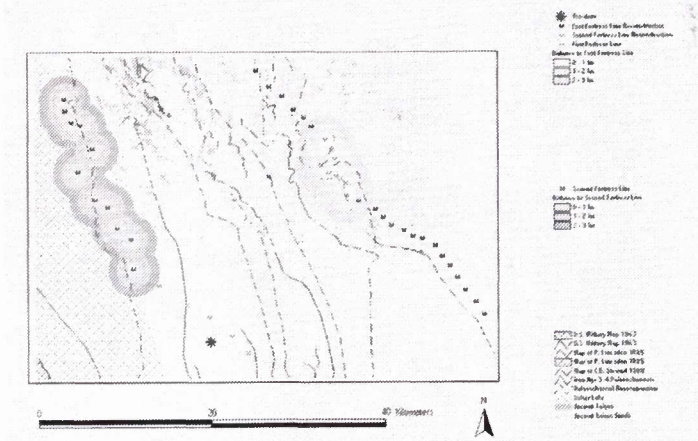

*Figure 13. The Iron Age Fortress Lines on the North-easternmost Part of Murghab Delta*

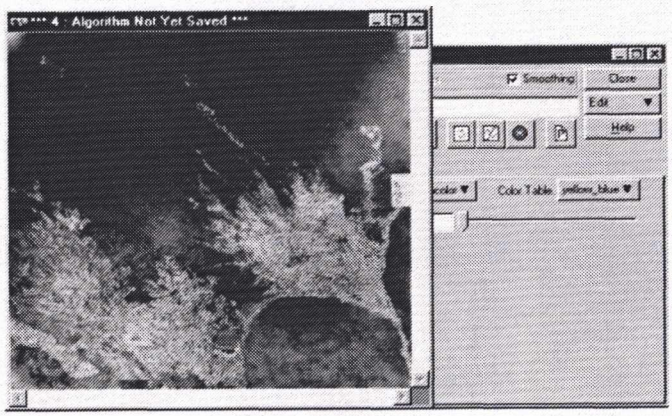


*Figure 14. The ERTS-1 1972 by an ER Mapper Elaboration: the Regression Step of the Murghab Delta and the Present Irrigation Area*

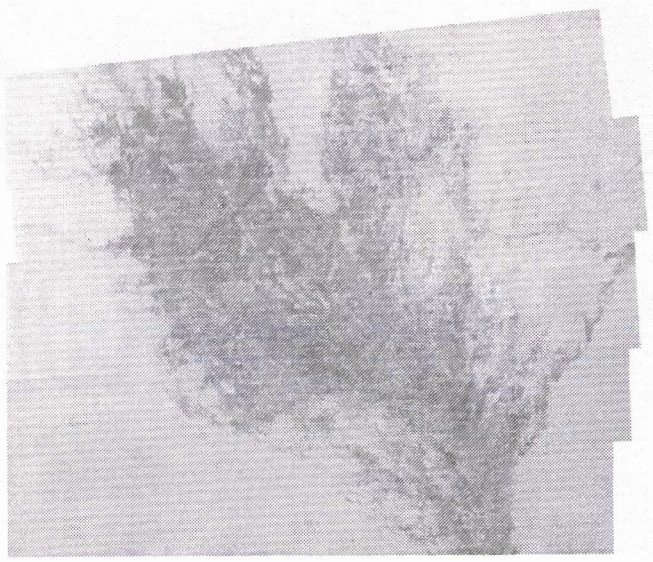

*Figure 15. The CORONA 1961-1974 Strip Mosaic: the Murghab Delta*