Published paper

Isserlin, B.S.J., Arvanitis, M., Jones, R.E., Karastathis, V., Papamarinopoulos, S.P., Stephanopoulos, P., Syrides, G. and Uren, J. (2008) *The Canal of Xerxes in Northern Greece: Fact or Fiction? Recent Geophysical and Geoarchaeological Investigations.* In: Facorellis, Y., Zacharias, N. and Polikreti, K., (eds.) Proceedings of the 4th Symposium of the Hellenic Society for Archaeometry. 4th Symposium of the Hellenic Society for Archaeometry, 28-31 May 2003, Athens, Greece. British Archaeological Reports (BAR S1746). Archaeopress , Oxford, England, pp. 59-64

The Canal of Xerxes in Northern Greece: Fact or Fiction? Recent Geophysical and Geoarchaeological Investigations

B.S.J. Isserlin,[1] M. Arvanitis,[2] R.E. Jones,[3] V. Karastathis,[2] S.P. Papamarinopoulos,[4] P. Stephanopoulos,[4] G. Syrides[5] and J. Uren[6]

[1] *University of Leeds, UK, r.jones@archaeology.gla.ac.uk*

[2] *Geodynamics Institute, National Observatory of Athens*

[3] *Department of Archaeology, University of Glasgow, UK*

[4] *Laboratory of Geophysics, Department of Geology, University of Patras*

[5] *Department of Geology, University of Thessaloniki*

[6] *Department of Civil Engineering, University of Leeds, UK*

Abstract: Herodotus describes how a canal was constructed in northern Greece by King Xerxes in around 480 BC to allow the Persian fleet into the Aegean in advance of its invasion of Greece. If so, this canal must have been a remarkable engineering operation for its time. This paper reports on the results of a non-invasive investigation at the supposed site of the canal on the 2 km wide isthmus of the Mount Athos peninsula. Geophysical, especially seismic survey, topographic survey and analysis of borehole sediments have played complementary roles in demonstrating that Herodotus' account was very probably correct.

Περιληψη: Ο Ηρόδοτος περιγράφει τον τρόπο με τον οποίο έγινε η διάνοιξη του διώρυγας στην Βόρειο Ελλάδα από τον βασιλιά Ξέρξη, για να καταστεί δυνατή η διάβαση στο Αιγαίο του Περσικού στόλου, κατά την εισβολή που επιχειρήθηκε 480 π.Χ. Εάν αυτό αληθεύει, πρόκειται για ένα αξιοθαύμαστο τεχνολογικό επίτευγμα για την εποχή του. Η εργασία αναφέρεται στα αποτελέσματα της γεωφυσικής διασκόπισης στην διερευνούμενη περιοχή της διώρυγας και σε πλάτος 2 χλμ. στο στενό που διαγράφεται επί της χερσονήσου του Αγ. Όρους. Τα αποτελέσματα των γεωφυσικών, σεισμοτεκτονικών και τοπογραφικών αποτελεσμάτων της έρευνας, καθώς και η ανάλυση των ιζημάτων των πυρήνων που λήφθηκαν, δείχνουν να επιβεβαιώνουν τις αναφορές που παρατίθενται από τον Ηρόδοτο.

Keywords: Geophysical survey; seismics; Xerxes; canal; coring; sediment analysis; ground-penetrating radar; radiocarbon dating

Introduction

The ancient Greek historian Herodotus (Histories VII 22-4) describes how a canal was constructed in northern Greece on the orders the Persian King Xerxes in 483-1 BC to allow the Persian fleet safe passage into the Aegean in advance of its invasion of Greece; he records that it was some 2 km long and was wide enough for two triremes to pass side by side. If this account is true, its construction must have been a remarkable engineering operation for its time. Although the canal has attracted scholarly attention over the years, no archaeological fieldwork was carried out to verify whether indeed it was a canal linked at both ends to the sea, or whether, as some have postulated, there was instead a slipway (diolkos) across the isthmus. Today the only visible remains are a depression in the central part of the isthmus.

To resolve this question, a British-Greek team has carried out over the last decade a non-invasive investigation at the supposed site of the canal which is situated on the Athos peninsula of the Chalkidiki (Fig. 1 inset). Geophysical (seismic, radar, electric and magnetic) and topographic surveys and analysis (and radiocarbon dating) of sediments from boreholes have all played important, complementary roles in the investigation in demonstrating the veracity of Herodotus' account. The results of the project have been published with different audiences in mind: Isserlin et al (2003) have reported the project's final stage and discussed the findings as a whole in an archaeological context, while the more technical aspects have been explored by Karastathis, Papamarinopoulos and Jones (2001) and Jones et al (2000). The present paper aims to give an overview of the project now that its current phase of field work is complete, to demonstrate the role of integrated input from geophysical and topographic surveys and analysis of sediments from cores, and to consider the progress of possible future work at the canal. In our mind, two main factors justify the need for such a paper; first, the results deserve to be presented to as wide an audience as possible since the object of this investigation - the canal - is unique (not only in Greece), and furthermore it is unlikely for logistical as well as financial reasons to be excavated by conventional archaeological means at least in the near future (but see Discussion; and Isserlin et al 2003, Appendix 1); second, the project can be viewed as a case study within the context of the increasing impact that geophysical and related survey is now making in Greek and more widely in Mediterranean archaeology (Sarris and Jones 2000).

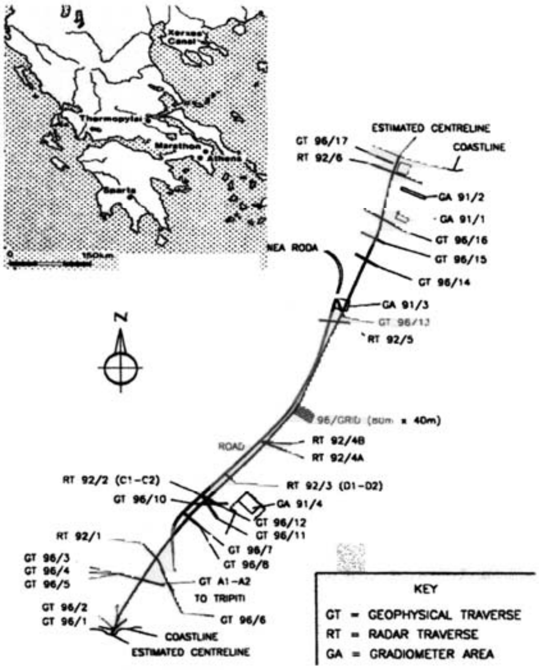

Figure 1(a). Plan of the canal represented by the centreline of the present-day lowest ground level (as estimated in 1991), showing the locations of the geophysical surveys. The site is marked on the inset map.

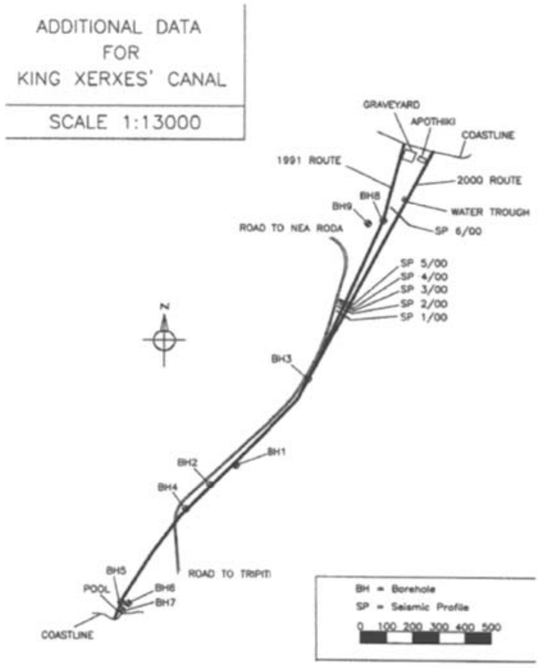

Figure 1(b). The locations of the boreholes (BH) and later seismic profiles along the course of the canal as estimated in 1991 and following revision in 2000.

The location of the canal

The presumed course of the canal lies at the narrowest point of the Mount Athos isthmus, amid a ricultural land. Today, from the sea at its northern end it passes close to the village of Nea Roda across an area of open flat, formerly marshy land enterin the central sector where the land level rises to a ma imum elevation of 1 .7 m above sea level, there is a lon natural depression which ives way to a stream bed that passes between two hills close to the sea at Tripiti. This picture of the canal's topo raphic environment is complicated by the fact that the area is one of hi h tectonic activity.

Sands, silts, red beds and alluvium are the main surface eolo ical features at the isthmus, and below them, enerally but not e clusively at a depth of at least 10 m, lie red bed sediments Syrides 1 0 . The choice of this location to construct the putative canal was a ood one since not only was it at the narrowest and lowest part of the isthmus, but the sediments would have been relatively easy to di out. To the northwest limestone and ranite outcrop, and there is neiss to the south-east.

Archaeological – historical considerations

Herodotus describes not only the events that led er es to order the construction of the canal but also how it was constructed. ut havin read Herodotus' account, it comes as a disappointment to find so little on the ground today that can be linked to this structure. Apart from the broad depression alon the central sector, there is an apparent absence of, for e ample, any infrastructure that mi ht be e pected to accompany the operation of a canal, from buildin s, breakwaters to harbour installations. n this situation, the counter-su estion that there was instead of a canal, a slipway diolkos alon which ships could be dra ed takes on more credibility. ndeed, Demetrius of Skepsis writin some three centuries later than Herodotus, claimed that the canal did not traverse the whole isthmus because of the hard, rocky terrain at the southern end at Tripiti. n recent times, opinions have been divided some North uropean travellers to reece in the 18th to early 20th century, such as Choiseul-Gouffier (1809) (see Fig. 2b , followed Herodotus, while ousin ry 1831: 1 3ff believed there was a diolkos. ocal views have been more divided between the two models.

The survey

The project developed a flexible and often experimental strate y, summari ed in rou h chronolo ical order in Table 1 that was capable of detectin and describin on the one hand a lar e, potentially deeply buried structure and, on the other, buildin s associated with that structure. Fig. 1a, b shows the locations of most of the geophysical

Survey	**Result**	**Publication in addition to Isserlin et al 1994; Jones et al 2000**
1. Walk-over survey 2. Topographic 3. Aerial	1. Roman pottery near the southern end of canal; Byzantine structures on the southern hill at Tripiti. Many ancient sites in the vicinity: ancient Acanthus, Sani and Ouranopoulis. 2. *c.* 6000 3-D readings, 1:2000 contoured map. Identification of a likely course of the canal based on present-day lowest ground level. 3. Several Greek Air Force overhead and oblique photographs	1. Isserlin (1991)
1. Resistivity soundings: 60m profiles; Schlumberger array at 5 m intervals 2. Electrical imaging	No clear demarcation of the canal's sides up to a depth of 30 m	
1. Magnetic (gradiometer) mapping mainly at the northern end to detect buildings 2. Magnetic (gradiometer) mapping over a building structure observed in an air photograph, situated to the east of the canal in its central sector 3. Magnetic profile (with proton magnetometer) of the canal	1. Anomalies were more likely associated with modern soil disturbance than with buildings 2. No anomalies found; the building may have been ploughed out 3. See text	3. Isserlin *et al* (2003)
Ground-penetrating radar (GPR): 80 and 120 MHz antennae, ten 50-120 m profiles	See text	
1. Seismic reflection and refraction profiles 2. Seismic tomography	See text	1. Karastathis *et al* (2001) 2. Isserlin *et al* (2003)
Sedimentological analysis of nine borehole cores, ranging in depth from 10 to 24 m	See text	
Radiocarbon dating of four sediments	See text	Isserlin *et al* (1996)
Satellite (LANDSAT-TM false colour) image	See text	Isserlin *et al* (2003)

Table 1: The techniques used in the Xerxes Canal Project

surveys and boreholes; the former were generally aligned as profiles at right angles to the supposed course of the canal. Operating conditions of the survey techniques and data processing methods are given in the papers referred to in Table 1. The most informative results emerged from survey in the central sector of the isthmus.

Beginning with the electrical survey, the pseudosections from resistivity soundings displayed at the top a 1-2 m thick high resistance layer of colluvium infill, giving way to progressively lower resistance values in the thick sand/silt layer to a depth of c. 30 m. There was no indication of a canal-like structure. In the corresponding magnetic profile across the canal, the infill gave a low intensity anomaly. The magnetic anomalies detected at the northern end were interpreted as the result of modern disturbance rather than as building structures associated with the canal. The depth of penetration of the GPR survey did not exceed 10 m owing to the relatively high water table; this, coupled with the lack of dielectric permittivity contrast between the infill and the surrounding more compacted host sediments, resulted in a failure to detect a complete canal-like outline. Instead, several episodes of (natural) infilling of the depression were evident, as was the apparent asymmetry of this depression which was also detected in some of the seismic data.

Following the initial promising seismic refraction and reflection profiles in the central sector, the technique was employed at points along the whole course of the canal. The results overall were highly satisfactory generally, and also specifically owing to the lower velocity values obtained in the infill as compared to those of the host material: Fig. 2a shows clearly the profile of the canal at one position in the central sector, and the picture resulting from 2-D inverse modelling techniques on data from a series of five profiles at the northern end appears in Fig. 3. Furthermore, the direction of the canal apparent in Fig. 3 differs from that originally determined on the basis of present-day lowest ground level (Fig. 1a) such that it is now likely the canal connected with the sea at least 50 m further east (Fig. 1b: 2000 route). The combination of seismic survey and analysis of borehole cores proved to be powerful for two reasons. First, the former estimated the

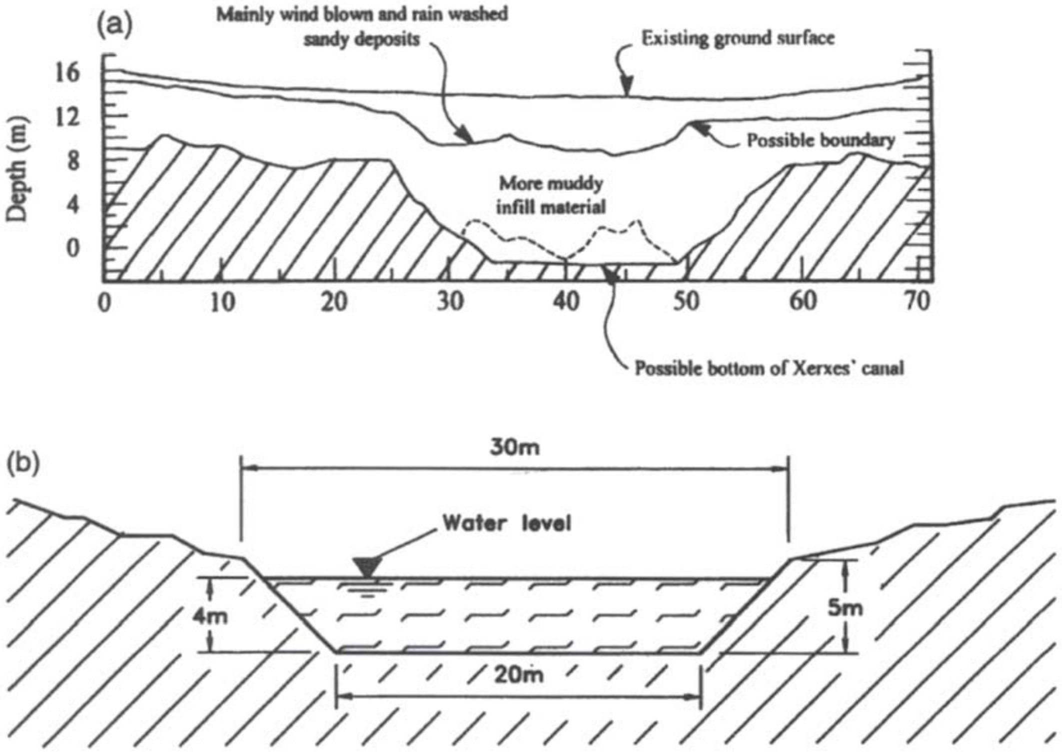

Figure 2. (a) Representation of the canal section (a) at Profile D based on the high resolution seismic refraction data following velocity analysis: velocity in the host material (shaded) 2170 m/sec, in the infill 1390 m/sec and in the top layer 380 m/sec. (b) according to de Choiseul-Gouffier (1809) (Isserlin et al 1996)

depth of the base of the canal below present-day round surface in the central sector to be c. 1 m, a value which coincides remarkably with the depth of the interface of the clay silt layers and the more compact red beds roups A and sediments respectively in Fi . 4 as observed in the sequence of sediments in borehole 3 H3 in Fi . 1b this interface surely represents the base of the canal Fi . 4 . Second, the combined methods resolved the issue of the diolkos model at the southern end: not only did there seem to be no serious obstacle from shallow bedrock there that would have prevented the canal bein e tended all the way to the sea, but there were no indications of a diolkos anywhere. Two notable features of the core sediments taken in the central sector were the absence of marine indicators that hints that the canal's direct links with the sea were limited in duration, and the presence of indicators that the canal fell into disuse probably rapidly by side collapse creatin in places stillwater marshy environments. Finally, althou h nothin is evident in the air photo raphs of the canal beyond the central depression, it is noteworthy that amon the draina e areas appearin in yellow in a ANDSAT-TM false-colour satellite ima e of the re ion is one traversin the isthmus in a direction remarkably similar to that proposed by the combined survey evidence marked 2000 route in Fi . 1b .

iscussion

Archaeolo ical interpretation of the pro ect's results can be summarised succinctly: across the 2 km isthmus a canal was very likely du , its top width bein c. 30 m and its base now buried some 1 m below present round level the canal would have been shallow, but more enerally apparently around 3 m deep. This description conforms fairly well to that iven by Herodotus, and it harmonises with the model accordin to one of the early travellers, de Choiseul-Gouffier (1809), shown in Fig. 2b. At both ends, the canal connected with the sea there is no ood reason to suppose there was a diolkos at the southern end. The canal seems not to have been of uniform construction, and nor does it appear to have had a lon life its main function fulfilled, it was probably not maintained and so fell into disuse rapidly. n this li ht it is perhaps not surprisin that no evidence was found for buildin s that could be associated with the canal's operation no doubt such buildin s e isted, but they were temporary and have lon since disappeared. verall, althou h the pro ect's ambitious aims have been largely fulfilled, the quality of the results was not uniform across the isthmus that the clearest results were consistently obtained in the central sector has been frequently alluded to, in contrast first to the

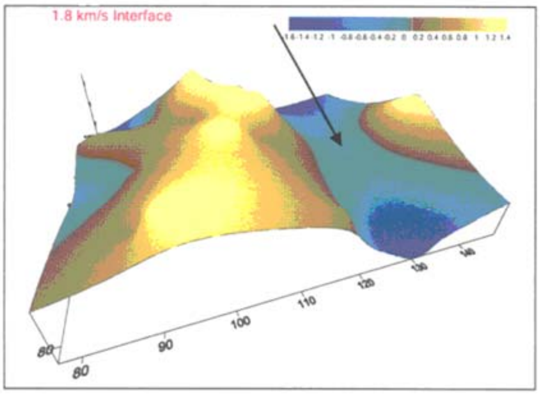

Figure 3. A visualization of the seismic refraction data obtained in the flat area at the northern part of the isthmus (SP 1-5/00 in Fig. 1b). It is based on a scheme connecting the subsurface points with the same acoustic velocity (1.8 km/s). The colour scale indicates the elevation (in m) of these points, the blue representing points below present-day sea level. On the right, an arrow marks the proposed course of the canal.

situation around T A1-A2 in Fi . 1a where the modern stream bed oins the canal depression towards Tripiti, and second to what is mentioned below in the plain at the northern end.

Turnin to the methodolo ies adopted, seismic survey was very well suited to the problem in hand, while the contribution from the other eophysical techniques was useful but less crucial. orehole corin was not only necessary in such a pro ect but the results that this approach provided from the sediment analyses were essential. That said, the borehole coring confronted two problems; first, the nature of the sediments was such that core loss was significant in some places. Second, whereas the decision where to locate the boreholes in the central and southern sectors was relatively strai htforward, the situation in the wide flat plain at the northern end was different; here, the partial picture obtained from the e ploratory few cores taken had little archaeological significance. The same remarks apply to the e ploratory use of radiocarbon datin to try and date the construction of the canal. As e pected, the dates from sediments taken ust above the base of the canal at two locations in the central sector were considerably older than the likely time of construction because of the presence of older' or anic components in the sediments. The point is that to obtain archaeolo ically meanin ful dates would require sediment samples for radiocarbon datin that would be too numerous to be justified in terms of cost and effort.

Looking to the future, although the project's field work as reported here is now completed, there are a number of avenues for further work. ne that has been reco nised for some time is the desirability of an underwater

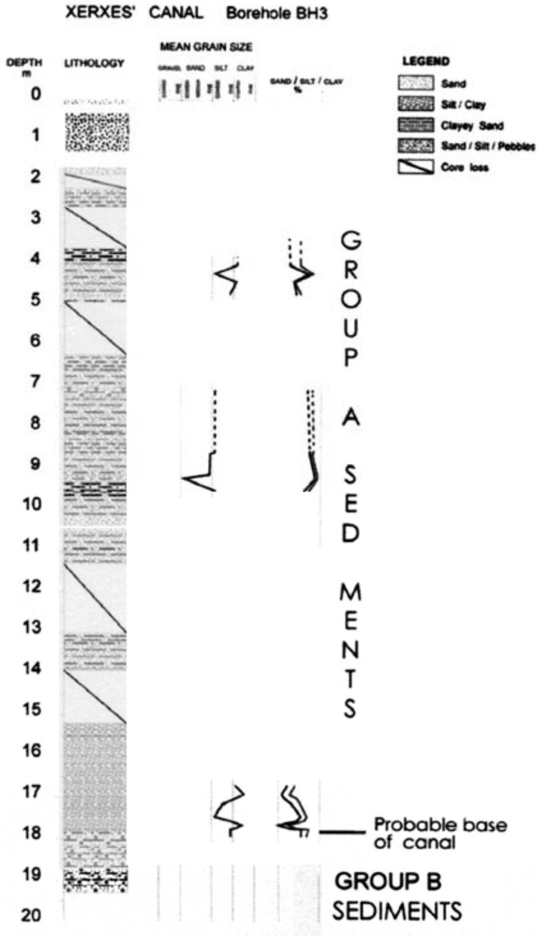

Figure 4. Lithological column of the borehole BH3 (see Fig. 1b). Ground level is at c. 14.1 m above present sea level. The Group A sediments are typically grey-brown to dark brown-blackish silty-clayey sands, silts-clays and coarse sands with scattered small pebbles, while Group B sediments are reddish brown coarse silty sands with varying proportions of clay and scattered small pebbles; they are more compact sediments than A. It is proposed the base of the canal lies at the interface of the Groups A and B sediments, c. 3.80 m below present sea level which is marked with a horizontal arrow.

reconnaissance of the two ends of the canal for indications of harbour installations and breakwaters, as well as for information supplementin that already obtained by apan elos and ambouro lou 1 on sea level chan es. Second, the opportunity for exploiting the potential of core sediments for environmental reconstruction has not been lost; Drivaliari and Syrides (2003) have already presented their preliminary environmental findings which they e pect to publish at a later date ma netic susceptibility measurements on the cores may also be valuable D. Kontopoulou, pers. comm.). Third, having defined the course of the canal with some confidence by geophysical survey there is sufficient associated topographic data to make a 3-D reconstruction of the canal. This could have direct educational value, as well as enhancin the presentation of the canal to visitors to the re ion, especially in the event that the proposed archaeolo ical park' at Nea Roda becomes a reality. ut, fourth and most provocative of all would the e cavation of a test section of the canal, as outlined by sserlin et al 2003: Appendi 1 , probably in the central sector. This would be a very challen in but in our opinion worthwhile enterprise. Finally, we note with interest the current ersian ar Shipwreck Survey off Mt Athos which is a collaborative effort of the reek phorate of Underwater Antiquities, the anadian Archaeolo ical nstitute at Athens and the Hellenic entre for Marine Research hitley 2004: 4 .

Ac no ledg ents

Many or anisations and individuals have made this pro ect possible. Here we wish to thank the Ministry of ulture for permission to carry out this pro ect, the ritish School at Athens, and NAT 's Science for Stability pro ram.

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