



**HAL**  
open science

# Quantitative Approach to the Diffusion of Obsidian in the Ancient Northern Near East

Christine Chataigner, Olivier Barge

► **To cite this version:**

Christine Chataigner, Olivier Barge. Quantitative Approach to the Diffusion of Obsidian in the Ancient Northern Near East. 35th International Conference on Computer Applications and Quantitative Methods in Archaeology (CAA), Apr 2007, Berlin, Germany. hal-01839312

**HAL Id: hal-01839312**

**<https://hal.science/hal-01839312>**

Submitted on 30 Jul 2018

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Christine Chataigner – Olivier Barge

## Quantitative Approach to the Diffusion of Obsidian in the Ancient Northern Near East

*Abstract:* Tracing the transport of obsidian in the ancient Near East has played an important role in identifying prehistoric trade networks. The quantitative aspect of these exchanges has until now been rarely studied, whether the weight of material transported, its correlation with the means of transport (carried by humans, by pack or draught animals, by boat), the number of hours or days necessary between the source and the archaeological sites. Obsidian sources located in the northern Near East (Eastern Anatolia, Transcaucasia) were extensively exploited between the 7<sup>th</sup>–3<sup>rd</sup> mill. BC. The GIS modelling and quantification of the provision of obsidian in this mountainous region have revealed the predominance of a direct mode of acquisition, based partly on transhumance. The ethnographic data and the accounts of travellers in past centuries contribute precious information, which clarifies and supports the results of the modelling achieved using the GIS.

### *Introduction*

Obsidian sources located in the northern Near East (Eastern Anatolia, Transcaucasia) were extensively exploited during the Neolithic, Chalcolithic and Early Bronze Age periods, between the 7<sup>th</sup> and 3<sup>rd</sup> mill. BC. In traditional studies of regional obsidian trade, the direct linear distance from the source is generally considered to be an essential parameter for explaining the quantity of material recovered on the archaeological sites (RENFREW 1977; PETERSON / MITCHELL / SHACKLEY 1997). However, studies (KELLER et al. 1996; BLACKMAN et al. 1998; BADALYAN / CHATAIGNER / KOHL 2004) carried out in Transcaucasia (*Fig. 1*) show that the factor of direct linear distance often does not apply. Most of the villagers of these prehistoric periods obtained obsidian from several sources, and the closest deposit was not necessarily the most desirable. In the whole of the corpus, only 40% of the sites are mainly supplied by the nearest source; 42% exploit the nearest source less than other ones, and 18% do not exploit it at all (BARGE / CHATAIGNER 2003). Other factors need to be considered, which is why we have constructed a GIS which takes distances into account, as well as the constraints for movement and the transport of obsidian from the sources to the sites.

### *Travel Costs*

The first stage of our analysis was to evaluate the nature and patterns of travel cost between the Trans-

caucasian sources of obsidian and the archaeological sites, in order to understand the cost factors actually involved for the prehistoric peoples who sought this material:

- Snow is abundant in winter above 2000 m and blocks access to obsidian sources located at high altitude, but this is only a seasonal constraint, as in summer these highlands become pastures which are frequented by transhumant shepherds.
- The vegetation is generally of steppe type and it was so at the beginning of the Holocene according to palaeo-environmental studies.
- The rivers are mainly narrow streams, and many fords enable crossing; it is the steep relief of the canyons through which the rivers flow, rather than the rivers, which presents difficulties.
- The topographical element, with elevations often higher than 3000 m and deep valleys, appears to be the main constraint for travelling.

Other, non-environmental factors will have also influenced the movement across the ancient landscape: political boundaries, social divisions, cultural taboo or attraction associated with certain sites; however these factors have little if any mark in the archaeological record and therefore can be difficult or impossible to reconstruct (BELL / WILSON / WICKHAM 2002).

Transport in the 7<sup>th</sup>–3<sup>rd</sup> mill. BC would have been either on human backs or on the backs of oxen, but not on the backs of equids, which were domesticated locally only in the Early Bronze Age. The effort of the bearer would have been a function of the weight carried. According to ethnographic studies,

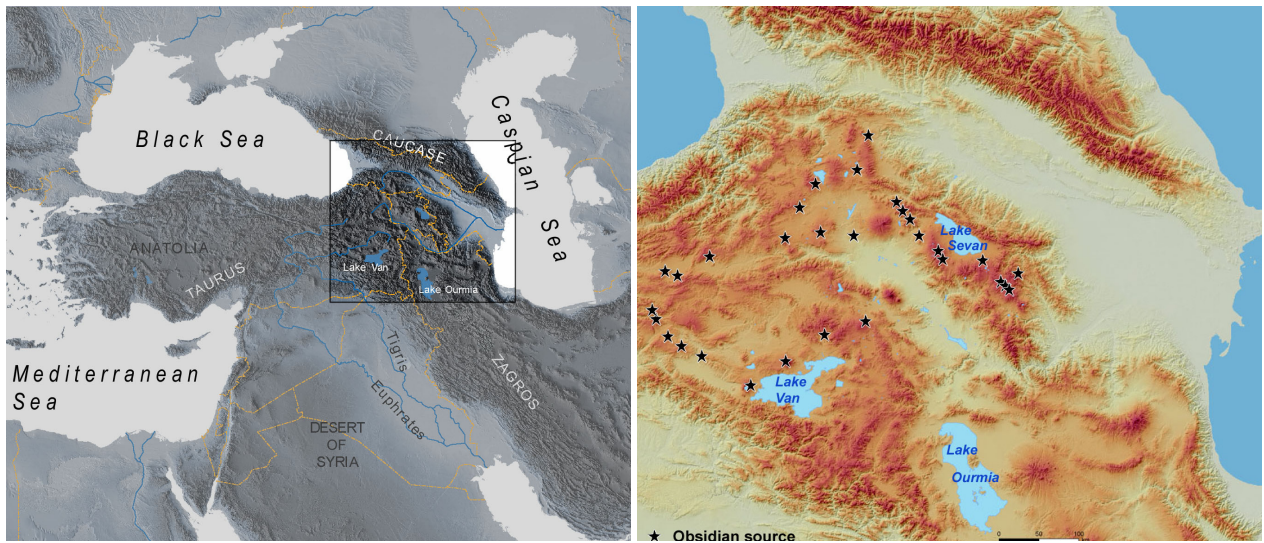


Fig. 1. Location of the obsidian sources in the northern Near East (Transcaucasia, Eastern Anatolia).

the pack oxen can carry loads of 50–90 kg, and human bearers loads of 20–80 kg or more. A recent experiment carried out with soldiers provides interesting information on the relations existing between the load of the backpack and the speed of marching, in ensuring that metabolic demands are retained at a bearable level: a) load 50 kg – speed 3.5 km/h; b) load 35 kg – speed 4.5 km/h; c) load 20 kg – speed 5.5 km/h (SCOTT / CHRISTIE 2004).

From this experiment, we can infer for a reasonably trained walker, an average speed on the flat of 5 km/h, for a load between 25–30 kg and a walking time of 7 to 8 hours per day. Even if it is difficult to extrapolate from the objects found in an excavation the total weight of obsidian which could be brought to the site, such a quantity of obsidian (30 kg) is already a considerable amount; for example, the neolithic site of Aratashen, in the Ararat plain (Armenia), has yielded more than 18,000 obsidian artefacts for a total weight of about 90 kg (BADALYAN et al. 2000).

The main travel cost being the topography, the cost surface of the GIS has been defined by the time needed for a walker depending on the slope and the distance. Two formulas have been proposed, with results comparable for the slopes less than 25° (near the maximal gradient accepted by mountain trekkers):

- (1)  $t = d / 6e^{-3.5|s+0.05|}$  (GORENFLO / GALE 1990), where  $t$  = time in hours,  $d$  = distance in km and  $s$  = slope, calculated as vertical change divided by horizontal change;  $e$  is the exponential function
- (2)  $t = (0.031 s^2 - 0.025 s + 1) * d/5$  (EASTMAN 1999; SCHNEIDER / ROBBINS 1996), where  $t$  = time in

hours,  $d$  = distance in km and  $s$  = slope angle in degrees.

These formulae are anisotropic, since the movements uphill and downhill will produce different results. However, in the particular case of obsidian procurement, the deposits are located at high altitude, with an ascending outward journey, but with very little load, while the return journey benefits in the descent, but with a much heavier load (obsidian blocks) and fatigue. Also in the hypothesis in which pack animals participated in the transport of the obsidian, the speed of descent would have been limited by the load carried and the difficulties of the terrain. Therefore, wishing to take into account the equivalence of effort which can exist between an ascent with no load and a descent with a load, we used Eastman's formula with an unsigned slope angle, in order to calculate full cost uphill, no cost cross-hill and full cost downhill.

The calculations were made for speeds corresponding to a loaded person walking (5 km/h), the results being not much different for draft animals. The ethnographic data indicate that the number of walking hours per day, which would be about 8 hours for a human bearer, is reduced to about 5 hours for draft animals, as they need to stop to graze.

The cost-weighted distance analysis functions enabled calculation on the one hand of the times accumulated to go from a given obsidian source to the archaeological sites and on the other hand to visualize the best route (or least-cost route) to take. The diffusion from a source of obsidian can be ex-



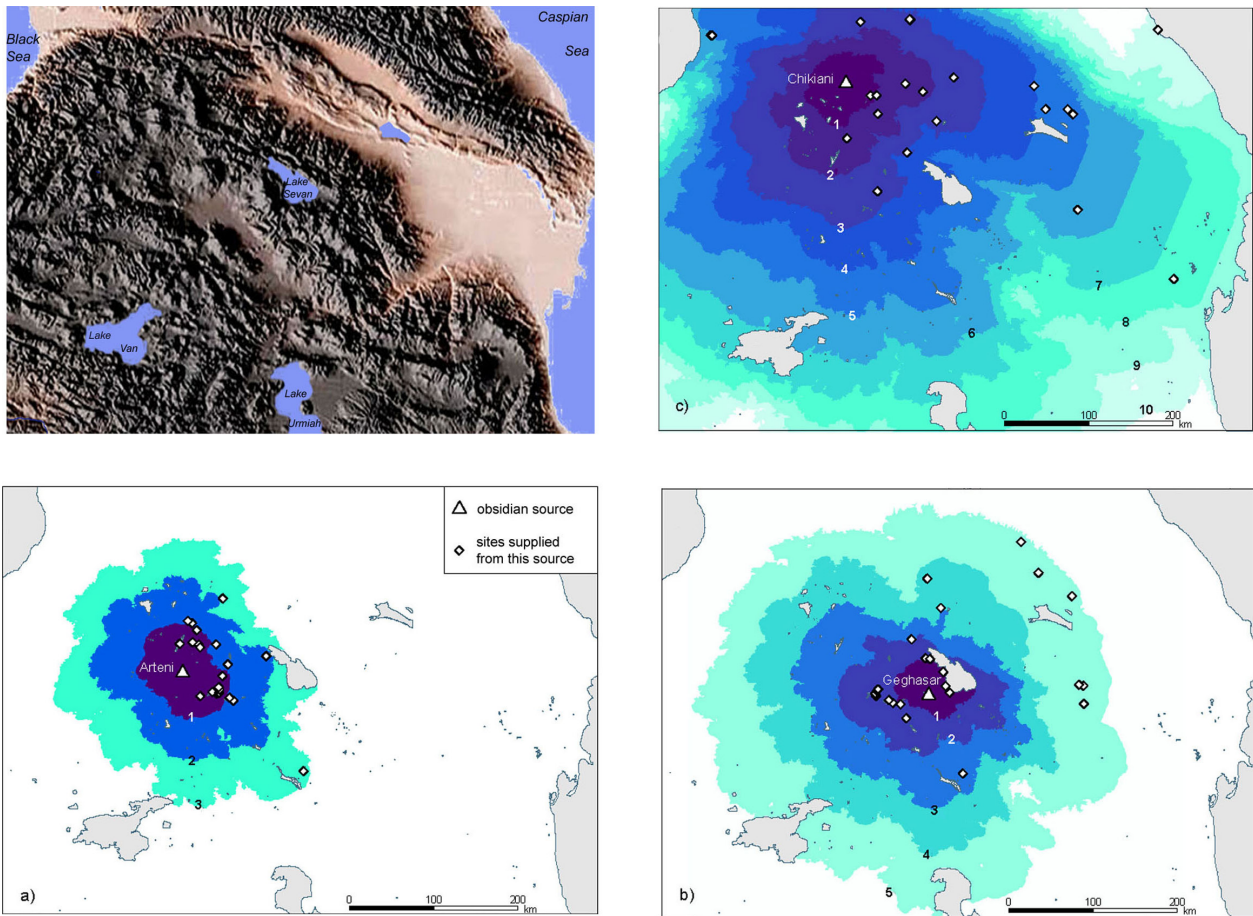


Fig. 2. Variability of the diffusion of the Transcaucasian obsidian sources: the examples of (a) Arteni, (b) Geghasar and (c) Chikiani.

pressed by isolines, which enable an understanding of the actual time necessary to travel from the source to the sites, and to compare for a given region the diffusion of obsidian from different sources (Fig. 2).

### *Overland Transport: Transcaucasia*

In the case of Transcaucasia, important variability can be noticed in the time calculated between sources and sites. In order to better understand where this variability comes from, let us examine a source, Arteni, on a finer scale (isochrones of 2 hours) (Fig. 3a). We notice that the frequency of the sites which have received obsidian from this source as well as the percentage of this obsidian in their material decreases dramatically above the isochrone of 15 hours.

The diffusion of the obsidian of Arteni can be represented by a histogram, which shows, by time ranges of 7 hours (or one day walk), the percentage of sites present in this range and the average per-

centage of obsidian which they use (Fig. 3b). The threshold at 14/15 h is clearly visible.

Arteni is situated at the periphery of the Ararat plain, at an altitude of about 1500 m, and is generally accessible all year round. Two other important obsidian sources, Gutansar and Hatis, are similarly situated (BADALYAN / CHATAIGNER / KOHL 2004, 450–453). The histograms of these three sources show a great similarity in the manner of diffusion (Fig. 3b, c). We notice at first a threshold at 15 hours (about 2 days walk). This threshold could correspond to the maximum acceptable time of direct procurement for the villagers.

For the villages which are situated between 15 to 42 hours from the source, the obsidian is present in reduced quantity: this probably signifies redistribution. Examination of the least-cost routes between the source of Arteni and these farther sites shows that they pass through intermediate sites, from which obsidian could have been passed on.

Other groups of obsidian sources (Geghasar, Sevkar) (BADALYAN / CHATAIGNER / KOHL 2004, 453–

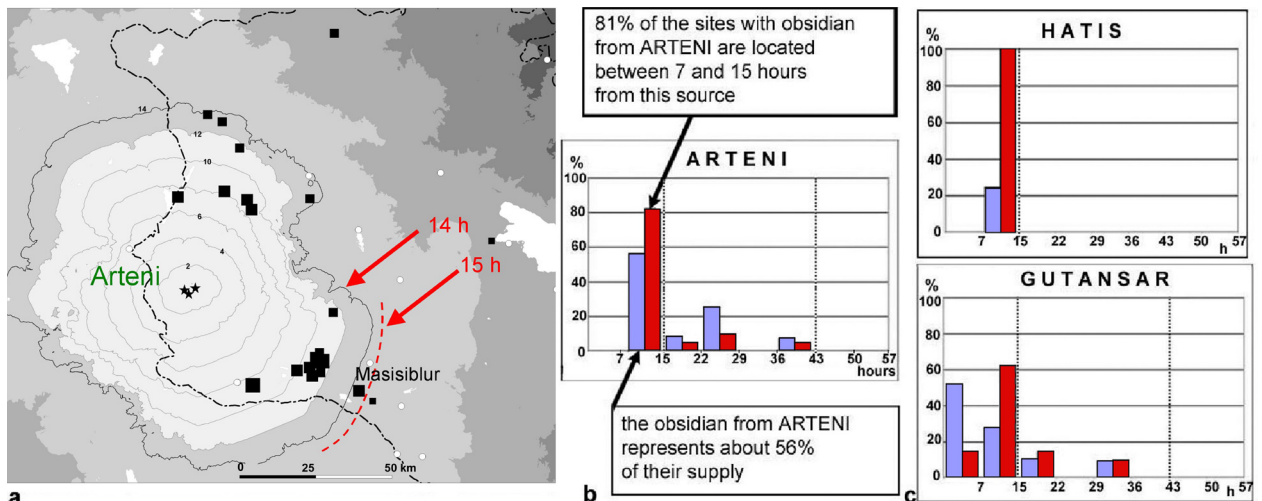


Fig. 3. Diffusion of sources of obsidian situated at the periphery of the plain of Ararat: (a) Arteni: quantitative distribution of obsidian. (b)–(c) Arteni, Hatis and Gutansar: variations in the quantity of obsidian and the number of sites in relation to the time needed for access.

455) are found on high plateaus at altitudes of 2500–3000 m. The histograms based on the time needed to access the sources indicate again the existence of a threshold at about 14/15 hours, a threshold which concerns here the quantity of obsidian and not that of the sites, which remain rare (Fig. 4a). The map of the modelled pathways shows that this first group of sites is located on the west shore of Lake Sevan, at an elevation of ca. 2000 m, under severe climatic conditions (Fig. 4b). These villages obtained their obsidian almost exclusively from the Geghasar source.

At 15 to 42 hours from the source, we notice a second group of sites, which, in the case of Geghasar, obtained up to 50% of obsidian from this source (Fig. 4a). If we examine the map of routes, we notice that, contrary to what has been observed for Arteni, these distant sites are linked directly to the source (Fig. 4b). It is probable that these villages, established in the valley of the Arax, were those of semi-transhumants, who drove their herds in summer to the high plateaus, like nowadays.

The ethnographic sources provide evidence of the practice of this custom in past centuries and the absolute necessity to act in this way, because of the very arid and very hot summer climatic conditions in the valley (MKRTUMYAN 1974).

A third group of sites is found even farther away, up to 70 hours by foot from the source (about 10 days for a human bearer and 14 days for pastoralists with their herd), and we notice in the case of Sevkar that the percentage of obsidian coming from the source can be high (Fig. 4a). Here again study of the routes

shows that some of these sites are directly linked to the source (Fig. 4b). This suggests the hypothesis of “long-distance” transhumants, whose herds grazed year-round in pastures, in the winter in the mild-climate steppes of Azerbaijan and in the summer on the high plateaus overlooking Lake Sevan. These transhumants brought down a noticeable quantity of obsidian, probably thanks to pack animals.

The example of Geghasar shows us also that several modes of distribution can exist for the same source, as there also seems to be evidence of redistribution from near settlement to near settlement for sites established along the Agstev river and in the Kura valley (Fig. 4b).

For the Sevkar source, we find three similar patterns of direct acquisition: 1) by villagers in the vicinity, in the Vorotan valley; 2) by semi-transhumants, settled along the shore of the Lake Sevan or in the Araxes valley; 3) by long-distance transhumants, coming from the steppes of Azerbaijan or from the lake Urmiah basin. This hypothesis of a significant transhumance suggested by the GIS is confirmed archaeologically by the excavation of the site of Godedzor, situated in the south-eastern part of the Lesser Caucasus (CHATAIGNER et al. in press).

This Late Chalcolithic settlement is situated at an altitude of about 1800 m in a region covered by snow from November to April. This settlement has yielded an enormous quantity of material, but very few architectural remains, suggesting that this village was deserted during the snowy winter. Almost all of the lithic industry of Godedzor is in obsid-

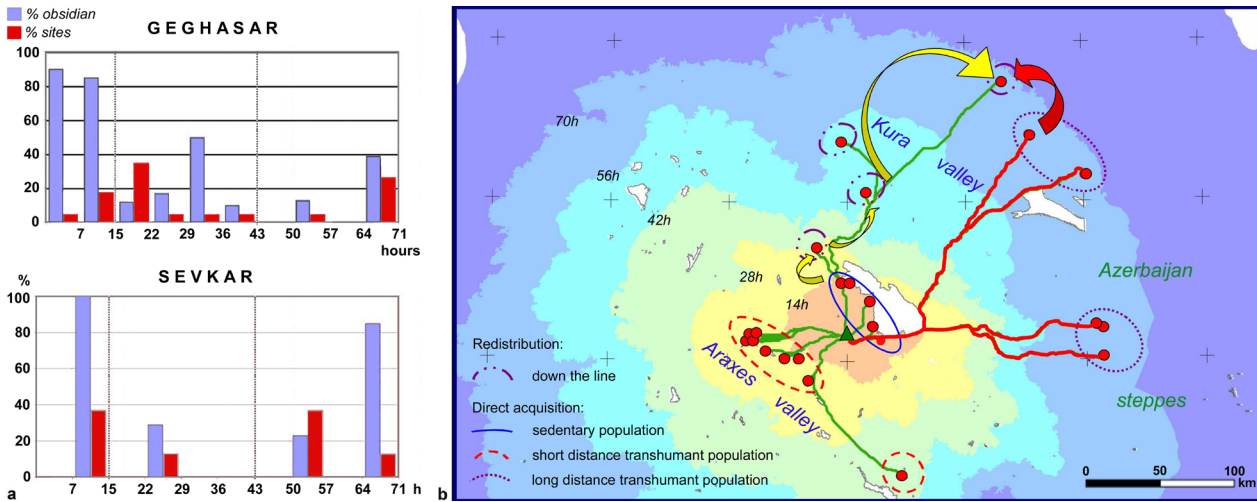


Fig. 4. Diffusion of the sources of obsidian situated at more than 2500 m in altitude: (a) Geghasar and Sevkar: histograms of the diffusion of obsidian in relation to the time needed for access. (b) Geghasar: least-cost pathways between the source and the sites.

ian. This material was obtained from the deposits of Sevkar and Bazenk, situated on the high plateaus which dominate the region. The inhabitants of Godedzor also possessed painted pottery which originated in north-western Iran, specifically in the basin of Lake Urmiah. Moreover, the herd was composed solely of sheep and cattle and several phalanges and vertebrae of oxen presented deformations due to carrying heavy loads.

All these elements suggest that Godedzor was a seasonal village and that its inhabitants were pastoralists who came from the basin of Lake Urmiah, to which they returned in the autumn with obsidian blocks from the Sevkar and Bazenk deposits.

### *Water Transport: Lake Van*

In the mountains of the northern Near East and Transcaucasia, the rivers are not navigable. On the other hand the three large lakes of the region could have been crossed by boat.

There is evidence for navigation in the ancient Near East at least since the 9<sup>th</sup> millennium, as the site of Shillourokambos on the island of Cyprus received obsidian from sources in Cappadocia (BRIOS / GRATUZE / GUILAINE 1997). There are no remains of Neolithic boats in the Near East, but it is probable that they were carved in tree trunks, like the one found on a Neolithic site of the 6<sup>th</sup> millennium in Italy (Lake Bracciano). To test the viability of this log-boat, a Czech team built a faithful copy

of the archaeological example, and made a voyage along the Mediterranean seacoast, with provisions and 100 kg of obsidian from Lipari (whose blocks were found on the Italian site) (TICHY 2000).

The replica built according to the find from Bracciano proved to be very good on the sea. The transport of obsidian was optimal, since the load was used as ballast. The average speed on the 800 km of the route was 4 km/h which meant mostly covering a distance of more than 50 km in a day.

The Nemrut Dag volcano, whose obsidian was widely diffused throughout the Near East from the beginning of the Neolithic, dominates the western extremity of Lake Van (Fig. 5). Its obsidian was diffused in particular towards the east, to Tilki Tepe; thus it seemed interesting to test whether transport by boat on Lake Van could have played a role in this pattern. We consequently carried out two calculations with the cost-weighted distance function, the first considering that the lake could have been crossed at the speed of 4 km/h, and the second considering that the lake had to be circumvented at the speed of man walking (5 km/h).

In the first case, the crossing would have taken about 25 hours. The accounts of travellers in past centuries refer to the crossing by boat from Tatvan to Van as not very dangerous and quite rapid (about 24 hours) (YERASIMOS 1991), which corresponds to an average speed of 4.2 km/h, which agrees with the log-boat experiment.

If the lake had to be skirted, the route along the north shore would have taken 45 hours. Reports of



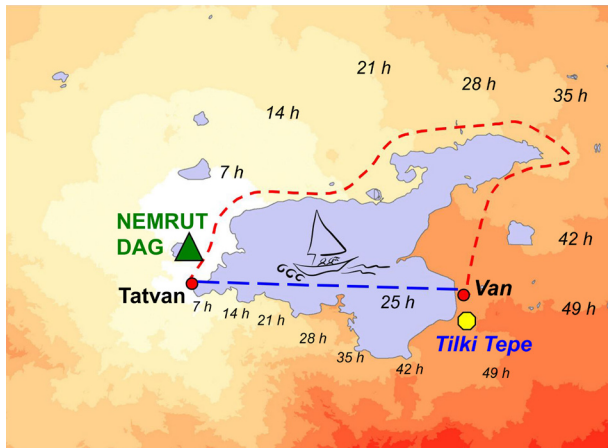


Fig. 5. Crossing or circumventing Lake Van.

travellers of earlier centuries confirm the length of this route, which required 8 days by horse, and stress that the southern route is geographically shorter but more difficult. According to our assumptions, the total time by the southern route is in fact equivalent to that for the northern route.

The quantity of obsidian found at Tilki Tepe is considerable, so the hypothesis of transport by boat, being more rapid and less tiring, is certainly plausible.

### Conclusion

In this initial stage of the study of the circulation of obsidian in the ancient Near East using a GIS, we have especially sought to verify the validity of the modelling. The systematic comparison between the hypotheses suggested by the GIS and other relevant data (archaeological, ethnographical or experimental data etc.) clarifies and supports the results of the modelling achieved using the GIS.

### References

- BADALYAN / CHATAIGNER / KOHL 2004  
 R. BADALYAN / C. CHATAIGNER / P. KOHL, Transcaucasian Obsidian: The exploitation of the Sources and their Distribution. In: A. SAGONA (ed.), *A View from the Highlands*. Archaeological Studies in Honour of Charles Burney. *Ancient Near Eastern Studies Supplement 12* (Leuven 2004) 437–465.
- BADALYAN et al. 2000  
 R. BADALYAN / P. LOMBARD / P. AVETISYAN / C. CHATAIGNER / J. CHABOT / E. VILA / R. HOVSEPYAN / R. WILLCOX / H. PESSIN, New data on the late prehistory of the Southern Caucasus. The excavations at Aratashen (Armenia): preliminary report. In: B. LYONNET (ed.), *The Cultures of the Caucasus from the 5<sup>th</sup> to the 3<sup>rd</sup> millennium B.C.* Editions Recherche sur les Civilisations (Paris 2000) 37–62.
- BARGE / CHATAIGNER 2003  
 O. BARGE / C. CHATAIGNER, The procurement of obsidian: factors influencing the choice of deposits. *Journal of Non Crystalline Solids* 323, 2003, 172–179.
- BELL / WILSON / WICKHAM 2002  
 T. BELL / A. WILSON / A. WICKHAM, Tracking the Samnites: landscape and communications routes in the Sango valley, Italy. *American Journal of Archaeology* 106, 2002, 169–186.
- BLACKMAN et al 1998  
 J. BLACKMAN / R. BADALJAN / Z. KIKODZE / P. KOHL, Chemical Characterization of Caucasian Geological Obsidian Sources. In: M. CAUVIN / A. GOURGAUD / B. GRATUZE / N. ARNAUD / G. POUPEAU / J. POIDEVIN / C. CHATAIGNER (eds.), *L'obsidienne au Proche et Moyen Orient: du volcan à l'outil*. BAR International Series 738 (Oxford 1998) 205–231.
- BRIOS / GRATUZE / GUILAINE 1997  
 F. BRIOS / B. GRATUZE / J. GUILAINE, Obsidiennes du site néolithique précéramique de Shillourokambos. *Paléorient* 23, 1997, 95–112.
- CHATAIGNER et al. in press  
 C. CHATAIGNER / P. AVETISYAN / G. PALUMBI / H. UERPMMANN, Godedzor, a Late Ubaid-related site in the southern Caucasus. In: R. CARTER / G. PHILIP (eds.), *The Ubaid and Beyond: Exploring the Transmission of Culture in the Developed Prehistoric Societies of the Middle East*. Proceedings of the International Conference on the Ubaid, Durham, April 20–22, 2006 (in press).
- EASTMAN 1999  
 J. EASTMAN, *Guide to GIS and Image Processing* (Worcester 1999).
- GORENFLO / GALE 1990  
 L. GORENFLO / N. GALE, Mapping regional settlement in information space. *Journal of Anthropological Archaeology* 9, 1990, 240–274.
- KELLER et al. 1996  
 J. KELLER / R. DJERBASHIAN / S. KARAPETIAN / F. PERINICKA / V. NASEDKIN, Armenian and Caucasian Obsidian Occurrences and Sources for the Neolithic Trade: Volcanological Setting and Chemical Characteristics. In: S. DEMIRCI / A. ÖZER / G. SUMMERS (eds.), *Archaeometry 94*. Proceedings of the 29th Symposium on Archaeometry (Ankara 1996) 69–86.
- MKRTUMYAN 1974  
 Y. MKRTUMYAN, Les formes d'élevage en Arménie orientale (in Russian). *Ethnography and Folklore of Armenia* 6, 1974, 7–92.

## PETERSON / MITCHELL / SHACKLEY 1997

J. PETERSON / D. MITCHELL / M. SHACKLEY, The Social and Economic Contexts of Lithic Procurement: Obsidian from Classic-Period Hohokam Sites. *American Antiquity* 62, 1997, 231–259.

## RENFREW 1977

R. RENFREW, Alternative Models for Exchange and Spatial Distribution. In: T. EARLE / J. ERICSON (eds.), *Exchange Systems in Prehistory* (New York 1977) 71–90.

## SCHNEIDER / ROBBINS 1996

K. SCHNEIDER / P. ROBBINS, GIS and Mountain Environments. *Explorations in Geographic Information Systems Technology* (Worcester 1996).

## SCOTT / CHRISTIE 2004

P. SCOTT / C. CHRISTIE, “Optimal” speed-load combinations for military manoeuvres. *International Journal of Industrial Ergonomics* 33, 2004, 63–68.

## TICHY 2000

R. TICHY, The sea navigation in early Neolithic Period. A contribution of experimental archaeology to the beginnings of Mediterranean neolithization (in Czech). *Archeologicke rozhledy* 52, 2000, 234–260.

## YERASIMOS 1991

S. YERASIMOS, Les voyageurs dans l’Empire Ottoman XIVe–XVIe siècles: bibliographie, itinéraires et inventaire des lieux habités. Publications de la Société Turque d’Histoire, Série 7,117 (Ankara 1991).

*Christine Chataigner  
Olivier Barge*

CNRS  
Université Lumière LYON 2  
Maison de l’Orient et de la Méditerranée  
Archéorient-UMR 5133  
7 rue Raulin  
69365 Lyon cedex 7  
France  
[christine.chataigner@mom.fr](mailto:christine.chataigner@mom.fr)  
[olivier.barge@mom.fr](mailto:olivier.barge@mom.fr)