In the two past decades, many studies have shown that the GIS (Geographic Information Systems) can be of great assistance to archaeologists, because their capacity for integrating spatial data (relief, hydrography, vegetation cover) enables a more realistic approach to certain behavioural factors in the study of past populations, such as those related to the circulation of people or goods across a territory. 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 at the archaeological sites (Fig. 1).

According to the “opportunistic model”, in the zone containing sites where consumers obtain their own supplies (“supply zone”), the quantity of obsidian decreases progressively as a function of linear distance from the source (“law of monotonic decrement”) up to a certain threshold (about 300 km). Beyond this threshold the quantity falls quickly, the sites of the “contact zone” receiving their obsidian through trade with neighbours located nearer the source (“down-the-line” exchange). The “centralized distribution model” enables the explanation as to why some sites far from the source possess a large quantity of obsidian, and attributes to these sites the role of “central places” (markets or political centres); from these sites obsidian is redistributed in a down-the-line mode. A third model, the “kin-based geographic model”, considers that the acquisition and the distribution of obsidian are based on networks woven by relationship (family, neighbours), and the material can thus be exchanged over very long distances.

However, studies carried out in Transcaucasia show that the factor of direct linear distance often does not apply. In the Ararat plain, the obsidian of the Arteni volcano represents only 30% of the supply at the Chalcolithic site of Mashtotsi Blur, at about 55 km from the source, but reaches 72% in a settlement of the same period situated at a distance of 70 km (Masisis Blur). Most of the villagers supplied themselves from several sources, and the closest deposit is not necessarily the most desirable. This is also true for Aratashen in the Ararat plain, for which only 18% of the supply comes from Gutansar, at about 40 km from the site, whereas 60% comes from Arteni, situated at about 50 km. 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.

Thus, the factor of direct linear distance often does not apply. This is why we have attempted to explore the capacity of the GIS (Geographic Information System) to take the relief into account in order to better understand how this factor could influence the distribution of obsidian.

The first stage of our analysis was to evaluate the nature and patterns of travel cost between the sources of obsidian and the archaeological sites, in order to understand what was actually involved for the prehistoric peoples who sought this material (distance covered, slopes climbed, weight of material transported). The second stage was to calculate, using the GIS, the time needed to journey between the sources of obsidian in Transcaucasia and the different archaeological sites of the 4th to 2nd millennia B.C., which were supplied with obsidian, and also to recreate the most efficient travel pathways through the region. In the third stage, another aspect involving the environment was explored, because travel cost is not just a reflection of slope and distance alone, but of factors like climatic conditions, vegetative cover, wetlands, crossing rivers or lakes, among others. We studied the impact of the

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1 Bell / Lock 2000; Bell et al. 2002; Bellavia 2002; De Silva / Pizzolo 2001; Whitley / Hicks 2001.
2 Renfrew et al. 1968; Peterson et al. 1997.
4 Seymour 1988.
5 Badalyan et al. 2004.
presence of large lakes on the circulation of obsidian, by analysis of two possible solutions: circumventing the lake or crossing it by boat. 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 left little if any mark in the archaeological record and therefore can be difficult or impossible to reconstruct.\footnote{Bell et al. 2002.}

**Nature and patterns of travel costs**

The topographical element has particular impact upon how people move from place to place, especially in hilly or mountainous regions. Even if it will never be the sole influence upon movement across the landscape, in simulating ancient and prehistoric landscapes it remains the most reliable.

**Distance**

Accounting for the relief, when travelling, implies that the route is not a straight line, but a broken line; the topography must be taken into account, obstacles avoided or crossed. The distance covered between two points A and B is the sum of these detours. In the GIS, the relief is represented in a raster mode by a grid (Digital Elevation Model), the Z-value associated to each cell being its altitude. In our study on Transcaucasia and the northern Near East, the size of each cell is 200 m × 200 m.

**Slope**

Relief is unevenness in elevation between two points A and B, which can be expressed in different ways: degree, slope, or percent of slope. For our villagers who set out to obtain obsidian, the steeper the slope, the greater was the effort required to walk. But if one considers that the “least slope” is the only criterion for moving from one place to another, the chosen routes will systematically follow the valleys and go around the mountains. For example, the route between Derbent on the Caspian Sea and the Kura valley will skirt the chain of the Greater Caucasus (Fig. 2).

However, in a mountainous region such as Transcaucasia, it is often more rational to link two valleys by crossing the ridges rather than circumventing them. Thus to go from Derbent to Kura, there is a road that crosses the Greater Caucasus by a pass and the journey is much shorter. In this case two factors intervene: the slope and the total distance. These are exactly the criteria taken into account by a mountain trekker to go from one point to another. Therefore, the time needed for a walker has been chosen as the “cost parameter” for the present GIS modelization.

**Time walking**

Two formulas have been proposed to evaluate the time needed for a walker according to the slope:\footnote{Formulas: (1) Gorenflo / Gale 1990; (2) Eastman 1999.}

\begin{align*}
(1) \quad t &= \frac{d}{6e^{3.5\sin(\theta)+0.05}} \\
(2) \quad t &= (0.031s^2 - 0.025s + 1) \cdot \frac{d}{5}
\end{align*}

in which \( t = \) time in hours, \( d = \) distance in km and \( s = \) slope in degrees.

The results (Fig. 3) are comparable for the slopes less than 25° (near the maximal gradient accepted by mountain trekkers), then clearly diverge beyond this gradient, the time proposed by formula (1) growing exponentially. For the present study, the formula proposed by J. R. Eastman, the most “pessimistic” for the gentle slopes, is chosen. These two formulas are isotropic: a given slope presents the same constraint, whether ascending or descending. But in reality, this hypothesis of isotropy is erroneous, as generally the descent is less time consuming than the ascent. Therefore, anisotropic algorithms were developed to account for both the degree and the direction of the slope.\footnote{De Silava / Pizziolo 2001.} But these anisotropic algorithms clearly present problems with steep slopes, because they would assume that moving down is very easy (low cost), when in fact it is as tiring as ascending. Moreover, in the particular case...
of obsidian procurement, the deposits are located at an altitude, with an ascending outward journey, but with very little load, while the return journey benefits from the descent, but with a much heavier load (obsidian blocks) and fatigue. And in the hypothesis in which draft 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. This is why it seems to us that an isotropic formula takes into better account the equivalence of effort that can exist between an ascent with no load and a descent with a load.

**GIS Spatial Analysis functions**

The Spatial Analysis functions of ESRI's ArcGIS (the “cost-weighted distance” and “least-cost path” analyses) enable calculation, on the one hand, of the time accumulated to go from one point to another on the map and, on the other hand, to memorise the pathways requiring the least effort and the least time in relation to the distance to be travelled and the slope.

In fact, each cell of the raster map is assigned a “cost”, representing the time required to cross it, which is calculated by Eastmann’s formula according to the size of each cell (200 m) and its slope (evaluated in relation to neighbouring cells). Then the user defines a source point (A) and the algorithm calculates the efforts accumulated to attain each point on the map from this source. It calculates the time walking between the centre of the source cell to the centre for each surrounding (nearest) cell; then it evaluates which has the minimum time, assigns a order number to that cell, which becomes the starting point of next iteration. In this way, the algorithm explores all the directions possible and retains for unit B the less total value as well as the route which enables access (Fig. 4).

In our application to obsidian procurement, we obtain for the archaeological sites distributed on the map the total time taken from a given obsidian source and the best route to take.

Even if it is obvious that these results should not be taken literally, that we are dealing with an estimate of times and with one of the solutions possible for the route, these results “put a question” to archaeology and provide fruitful paths of investigation.

Fig. 3. Comparison of the two time-walk formulas.

Fig. 4. Theoretical example of the calculation of the times accumulated to go from a source point (A) to any other point (B) on the map.
More than 20 sources of obsidian are scattered across the Lesser Caucasus, in the territories of Armenia, southern Georgia and western Azerbaijan (Fig. 5). The systematic characterization of these Transcaucasian obsidian sources was achieved through geochemical analyses and fission-track dating, and this geological data served as a base for determining the origins of an important corpus of artefacts from sites dating between the 6th and the end of the 2nd millennium B.C.9 We will analyse here the circulation of obsidian for the sites of the 4th–2nd millennia B.C.

Application to obsidian diffusion in Transcaucasia

More than 20 sources of obsidian are scattered across the Lesser Caucasus, in the territories of Armenia, southern Georgia and western Azerbaijan (Fig. 5). The systematic characterization of these Transcaucasian obsidian sources was achieved through geochemical analyses and fission-track dating, and this geological data served as a base for determining the origins of an important corpus of artefacts from sites dating between the 6th and the end of the 2nd millennium B.C.9 We will analyse here the circulation of obsidian for the sites of the 4th–2nd millennia B.C.

Maps of accessibility

Graphically, the GIS “cost-weighted distance” analysis expresses the diffusion from a source of obsidian by a gradation of colours, corresponding to the values taken by the time accumulated at each point. The user can define curves of iso-values: for example, every seven hours, which would correspond to the average walking time per day for a person on foot, accompanied by a draft animal or a herd, as the ethnographic studies suggest.10 In fact, the mode of transport used in the 4th to 2nd millennia would have been by foot, but the use of pack animals or draft animals for carts is probable, shown below in the example of Godedzor.

The curves of isovalues 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. 6):

- the source of Hatis, located in the eastern part of the Ararat plain, had the most restricted diffusion, having been exploited only by the villages established in the south and nearby, in the valley of the Araxes;
- the sources of Arteni and Gutansar were abundantly exploited, but in a regional fashion, as the diffusion of their obsidian concerns mainly western Armenia;
- the abundant flows of the Gegham range (Gegharsar, Spitaksar) and the Syunik region (Sevkar, Satanakar, Bazenk) had a wider distribution, which reached the Kura basin in the north and that of Lake Urmiah in the south;
- the source that clearly had the widest diffusion was the Chikiani volcano, located in southern Georgia, on the eastern edge of the Djavakheti range. It dominates the valley of the Khrami river, which is a tributary of the Kura. The area over which the obsidian from Chikiani was largely distributed extends across the Transcaucasian Depression between the shores of the Black and the Caspian seas.

Diffusion from sources at low altitude (less than 2000 m)

We notice important variability in the diffusion of the sources in the case of Transcaucasia. In order to better understand where this variability comes from, let us examine one source, Arteni, on a finer scale (isochrones of two hours). We notice that the frequency of the sites that have produced obsidian from this source as well as the percentage of this obsidian in their material decreases dramatically above the isochrone of 15 hours (Fig. 7). The diffusion of the obsidian of Arteni can be viewed as an histogram, representing, by time ranges of seven hours, the percentage of sites present in this range (in grey) and the average percentage of obsidian which they produce (in black) (Fig. 8). The diffusion pattern presented by Arteni is similar to that of Hatis and Gutansar: these three sources are situated at the periphery of the Ararat plain and their flows, extending at an altitude ranging between about 1400 and 2000 m, are generally accessible year-round. Again we notice clearly a threshold at 14/15 hours (about two days’ walk), which could correspond to the maximum acceptable time of direct procurement for the villagers. For the villages that are situated at least 15 hours from the source, the obsidian

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10 Mkpyumy 1974, 55.
Fig. 6. Maps of accessibility to the main Transcaucasian sources of obsidian (iso-values: every 14 h).
is present in reduced quantity (8% at Jrahovit); this probably signifies redistribution. Examination of the routes of least cost between the source of Arteni and these farther sites shows that they pass through intermediate sites, from which obsidian could have been passed on (Fig. 9).

**Diffusion from sources at high altitude (2500–3000 m)**

Another group of obsidian sources in Armenia shows diffusion over a very great distance, particularly Sevkar (in the southeast of the country) and Geghasar overlooking Lake Sevan. These deposits are found on high plateaus at altitudes of 2500 to 3000 m and are covered by a thick layer of snow from October to April; they are inaccessible during this period. During the summer, however, these high areas are travelled by many transhumants.

**Different modes of diffusion**

The histograms based on the time needed to access the sources (Fig. 10) indicate again the existence of a threshold at about 14/15 hours. This threshold concerns here the quantity of obsidian and not that of the sites, which remain rare. The map of the modelled pathways shows that this first group of sites is located on the western shore of Lake Sevan, at an elevation of c. 2000 m, under severe climatic conditions. These villages obtained their obsidian almost exclusively from the Geghasar source (Fig. 11).

At more than 14 hours we notice a second group of sites, 15 to 42 hours from the source, which, in the case of Geghasar, have produced up to 50% of obsidian from this source (Fig. 10). If we examine the map of routes (Fig. 11), we notice that, contrary to what has been observed for Arteni, these distant sites are linked directly to the source. It is probable that these villages, established in the valley of the Araxes, were those of semi-transhumants, who drove their herds in summer to the high plateaus, like nowadays. Ethnographic sources provide evidence of the practice of this custom in past centuries and the absolute necessity for the farmer-herders of the Araxes valley to act in this way, because of the very arid and very hot summer climatic conditions in the valley.11 When several possible routes exist, the GIS model reveals the least difficult and potentially the most used one. This is true for the track, which could have been followed by the inhabitants of Kulitepe in Nakhichevan to seek obsidian at Geghasar (represented in 50% of the samples analysed from this site) by ascending the valley of the Araxes, then crossing the Vardenis range through a pass at 2400 m. In the Zagros mountains this pattern of seasonal pastoral movement is referred to as “short-range vertical transhumance”. This pattern involves village-based shepherds moving with a village herd up into the high mountains during the summer. Usually the majority of the villagers stay behind near the ripening crops.12

A third group of sites is found even farther away, up to 70 hours by foot from the source, and we notice, in the case of Sevkar, that the percentage of obsidian coming from the source can be high (Fig 10). Here again study of the routes shows that some of these sites are directly linked to the source (Fig. 11). This suggests the hypothesis of “long-distance” transhumants, whose herds grazed year-round in pastures in the mild-climate steppes of Azerbaijan during the winter and on the high plateaus overlooking Lake Sevan during the summer. These transhumants brought down a considerable quantity of obsidian, probably thanks to pack animals.

Ethnographic sources of the 19th and the beginning of the 20th centuries emphasize that the pastures of the Lesser Caucasus were used by Armenians, but also by other populations of Transcaucasia living at the periphery of the Lesser Caucasus (Georgians, Azeris, Kurds), who came from villages situated at a distance of 100 km or more.13 The Azeris travelled to the pastures of south-eastern Armenia (Syunik),

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11 Мкртчян 1974, 52.
12 Henrickson 1985, 18.
13 Мкртчян 1974, 52; 55.
and those in the north-east and north (Tavush, Lori), the Georgians to pastures in the north (Lori) and the north-west (Shirak). The tradition of a long distance transhumance between the lowlands of Azerbaijan and Georgia and the high pastures of the Lesser Caucasus has thus existed for a long time. Such migrations are also attested in the Zagros mountains, where the “long-range” or “large-scale long-distance” nomadism involves semi-annual, seasonal migration of the entire population of animals and people over relatively long distances (ranging from roughly 100 to over 500 miles) in an alternation between cool upland pastures in summer and warm lowland pastures in winter.14

The example of Geghasar also shows us that several modes of redistribution can exist for the same source, as there also seems to be evidence of redistribution from near settlement to near settlement for several sites established at a middle or long distance from the source, through the valley of the Agstev (Fig. 11).

For the Sevkar source (Fig. 12), we find the 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 Azerbaidjan or from the lake Urmiah basin.

14 Henrickson 1985, 17.
This hypothesis of a great transhumance suggested by the GIS is confirmed archaeologically by the excavation of the site of Godedzor, situated in south-eastern Armenia (region of Syunik).

The example of Godedzor

This Late Chalcolithic settlement\(^{15}\) (end of the 5th millennium B.C.) is situated near Angeghakot in the Sisian province, at an altitude of about 1800 m. This region is covered by snow for six months, from the beginning of November to the end of April (Fig. 13). This settlement has yielded an enormous quantity of material (pottery, lithic and bone industries), but very few architectural remains (vestiges of circular walls in the latest horizon), which suggests that this village was deserted during the snowy winter.

Almost all of the lithic industry of Godedzor was of obsidian (Fig. 14a). This material was obtained from the deposits of Sevkar and Bazenk, situated on

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\(^{15}\) Godedzor is currently being excavated by P. Avetisyan (Institute of Archaeology, Yerevan) as part of the French-Armenian “Caucasus” mission, directed by C. Chataigner (Archéorient, C.N.R.S., Lyon) and financed by the French Ministry of Foreign Affairs.
Fig. 11. Models of least-cost pathways for Geghasar.

Fig. 12. Diffusion pattern presented by the source of Sevkar.
the high plateaus that dominate the region, or collected in the Vorotan River, whose upper tributaries flow across these obsidian flows. Obsidian from the Sevkar deposit is known to have reached the Lake Urmiah basin as soon as the beginning of the 6th millennium B.C., since its signature was identified in artefacts from the Neolithic settlement of Hajji Firuz in the Solduz plain, south of the lake. And this obsidian did not diffuse more towards the south; it remained completely unknown in sites in Mesopotamia, whereas the source of Nemrut Dag on the western shore of Lake Van, which is also attested at Hajji Firuz, was widely diffused in the whole of the “Fertile Crescent”.

The inhabitants of Godedzor also possessed painted pottery, which originated in north-western Iran, specifically in the basin of Lake Urmiah. On this well-fired fine pottery, the paint is matt black or very dark brown, and the decorative motifs (fairly standardised) consist of bands of simple zigzag or wavy lines that run horizontally along the neck and the body of the container, creating horizontal spaces that are filled with triangular, trapezoidal and rectangular densely cross-hatched metopes (Fig. 14b). These painted motifs have close parallels with similar productions from Pisdeli Tepe, a settlement located in the Solduz plain (like Hajji Firuz), in the second half of the 5th millennium B.C.

Herds were composed solely of sheep and cattle, which is an indication of mobility; the domestic pigs, animals which indicate sedentarism, could not be securely identified. Moreover, the phalanges and one vertebra of a young ox exhibited deformations due to carrying heavy loads (Fig. 14c). Therefore, the use of pack animals or draft animals for carts is highly probable.

Ethnographic examples of the 19th century indicate that the farmers who ascended to the high pastures carried all their material on draft animals, not only horses but also donkeys and sometimes oxen.

Where conditions permitted wheeled transport, they used different types of wagons to carry indispensable loads (equipment for milking, bedding, supplies,
building materials if there were no trees in the places to which they travelled). All of 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 and artefacts.

The practice of the long distance transhumance is a phenomenon, which appears to have developed during the 5th millennium B.C. According to E. Henriksen, the growth of mobile pastoralism in the Zagros highlands was the result of three intertwined processes, which occurred during the second half of the Chalcolithic era: population growth, a climatic shift (cooler and wetter following 4600 B.C.) and the economic interest in highland resources for the emerging lowland polities. The general deterioration of the climate at the end of the middle Chalcolithic period, accompanied by overgrazing, is also emphasized by K. Abdi, who considers it likely that more and more people then turned to mobile pastoralism as a viable subsistence strategy.

Crossing or circumventing lakes

Any study of movement through an ancient landscape should use a topographic model as its foundation, upon which additional models can be constructed, incorporating further aspects of environmental and non-environmental data. In fact, each element of the map (points, like archaeological sites; lines, like river courses; surface, like lakes or marshes) can be given a special cost, either by calculation or by choice. For example, the user can decide that a lake can be crossed or not and assign different costs to this lake.

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. In the 5th to the 4th millennia, its obsidian was diffused in particular towards the east, to Tilki Tepe. Thus, it seemed of interest for this study to test whether transport by boat on Lake Van could have played a role in this pattern. We carried out two calculations with the “cost-weighted distance” function, the first in considering that the lake could have been crossed at the same speed as a man walking on a flat surface (5 km/hour), which seems plausible for a small boat with a somewhat heavy load, and the second in considering that the lake had to be circumvented.

In the first case (Fig. 15a) the isochrones of seven hours indicate to us that the crossing would have taken about 20 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). If the lake had to be skirted (Fig. 15b), the route along the north shore would have taken 45 hours. The travellers of earlier centuries confirm the length of this route, which required eight days by horse, and they also stress that the southern route is geographically shorter but more difficult. For the GIS, the total time by the southern route is in fact equivalent to that for the northern route.

At Tilki Tepe, the obsidian from Nemrut Dag represents 23% of the supply; this quantity is relatively large and suggests two hypotheses:

- either the inhabitants of Tilki Tepe drove their herds in semi-transhumance up the slopes of the Nemrut Dag, and brought back obsidian by foot with their animals. However, this journey would have occurred only once a year and obviously would not have permitted them to bring back a quantity of material that was sufficient to ensure a redistribution towards the sites of Iran and Iraq.

Fig. 15. Comparison between sailing time crossing Lake Van and walking time circumventing the lake.
– or the inhabitants took obsidian several times during the summer season, by crossing the lake by boat. This would seem all the more plausible as the main part of the obsidian at Tilki Tepe came from elsewhere, from Meydan Dag on the north-east shore of Lake Van. This volcano is closer to the village (about 14 hours by foot) and was probably preferred for the summer pastures.

**Conclusion**

The use of the spatial analysis functions of the GIS permits a more realistic understanding of the circulation of obsidian for the time of travel and the direction of the routes. The calculation of travelling time shows that the quantities of obsidian found at sites drop dramatically, when the sites are farther than 15 hours’ (two days) walk from the source. The similarity of this threshold for the different sources suggests that this corresponds to the maximum time accepted by the populations for direct procurement. A second mode of direct acquisition was the collection of material during transhumance, a widespread phenomenon in the 4th–2nd millennia B.C., whether the transhumance for the populations of the middle basins of the Araxes and the Kura or the long-way transhumance for more distant populations, situated in the steppes of Azerbaijan or the basin of Lake Urmiah, as confirmed by both the ethnographic data and the “least-cost” pathways modelled by the GIS.

In fact, the least-cost network modelled by the GIS differs largely from that of the known routes of the historical period, which have been reconstructed through the accounts of travellers of the 14th to 19th centuries. These paths of communication, which were taken by caravans, follow the valleys and go around the mountains (Fig. 13). The two networks (least-cost pathways and historical routes) partly follow the same circuits for those routes, which correspond to a gradual redistribution of the obsidian. Thus Kültepe of Nakhichevan, situated in the eastern part of the valley of the Araxes River, is more than 25 hours from the first source of obsidian; however this material is abundantly represented on the site and its sources are diverse: Sevkar, Geghasar, Gutansar, Arteni and a source in the Kars region. This abundance and diversity can be explained, besides the practice of transhumance for the sources at high altitude (Geghasar, Sevkar), by the location of Kültepe on an important route along the left bank of the Araxes, leading from eastern Turkey (region of Erzurum) to the northwest of Iran (basin of lake Urmiah) (Fig. 13). Such a communication network enabled the exchange of various materials for obsidian: Kültepe is situated near a place where salt was mined in Antiquity, and rich copper minerals are found in the mountains of the Lesser Caucasus, not far from the site.

Thus, the systematic comparison between the hypotheses suggested by the GIS and other relevant data (obsidian procurement analysis, archaeological data, ethnographical data) constitutes an effective step. In fact, this attempt to transform strictly environmental parameters into representations of travel effort and route preferences should be seen as a means to begin the process of using our existing environment to logically deduce and understand the ways in which prehistoric peoples may have used the same variables cognitively and behaviourally.26

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Abstract

In traditional studies of regional obsidian trade, the direct linear distance from the source is generally considered to be an essential parameter. However, studies carried out in Transcaucasia show that this factor often does not apply. Therefore, we have attempted to explore the capacity of the GIS (Geographic Information System) and thereby take the relief into account, in order to better understand how this factor could influence the distribution of obsidian.

The spatial analysis features provided by GIS made it possible:

- to establish maps of accessibility to the sources of obsidian from each of the archaeological sites by calculating the time of access as a function of distance and relief. A threshold appears, which corresponds to the maximum time accepted by the population for direct procurement; beyond this threshold, the quantity of obsidian is reduced and appears to be related to gradual redistribution or to a transhumance process;
- to model the pathways between the sources and the sites, according to the least incline or to the least topographical constraint. The pathways in common correspond to permanent communications routes; the lines induced by topographical constraints indicate routes joining valleys through a pass or transhumance pathways.

Travel cost is not just a reflection of slope and distance alone, but of other environmental and non-environmental factors. As non-environmental factors (political boundaries, social diffusion) have left little if any mark in the archaeological record, we explored another aspect involving the environment. We studied the impact of the presence of large lakes like Lake Van on the circulation of obsidian, by analysis of two possible solutions: circumventing the lake or crossing it by boat.

Résumé

При рассмотрении вопроса о распространении обсидиана, главным критерием традиционно принято считать расстояние до места его добычи. Однако, исследования, проведенные в Закавказье, доказывают, что этот критерий не всегда является приемлемым. Используя систему ГИС, мы предприняли попытку изучения особенностей рельефа и их влияние на процесс распространения сырья.

Данные, полученные при помощи ГИС, дали возможность составить карты доступа к месторождениям обсидиана отдельно для каждого археологического памятника. В результате была определена ограниченная область распространения обсидиана, соответствующая максимальному отрезку времени, необходимого для его транспортировки на данный памятник. Распространение обсидиана за пределами области может быть связано с сезонным перегоном скота на новые пастбища.

Применение системы ГИС дало возможность смоделировать пути транспортировки обсидиана с учетом особенностей рельефа, вплоть до небольших склонов. Эти пути, в общем, совпадают либо с известными торговыми маршрутами, либо с маршрутами сезонного перегона скота.

При рассмотрении вопроса транспортировки сырья необходимо учитывать не только природные, но и другие факторы, например политические или социальные, которые, однако, не всегда можно выявить в результате археологических исследований. Поэтому, учитывая то, что находки из обсидиана распространены во всех регионах вокруг озера Ван, нами рассматривается оба пути его транспортировки: как наземного, в обход озера, так и водного, предполагающего пересечение озера с помощью лодок.