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Fossil Volcanism and Archaeology : the North Yemen Highlands

1. Fossil volcanism : concept and study area

In this paper an examination is attempted of the interrelationships between archaeologically known societies and fossil volcanism. The concept of « fossil » volcanism itself is introduced as a potentially useful tool in the human ecological evaluation of a specific set of landscape types. An attempt at formalizing this concept and its attendant implications is also offered.

The case study which forms the basis of this paper is part of a broader archaeological investigation of North Yemen, in the southwestern Arabian Peninsula. Since 1983-84 an Italian archaeological mission, in cooperation with the government of the Yemen Arab Republic, has been establishing prehistoric and early historic sequences in several parts of the country. In the plateau region, or the Highlands, prehistoric archaeology has brought us into contact with a harsh, high-altitude volcanic environment with a long and varied record of Holocene sites. Particular attention is given to some characteristics of this environment and its ecology on the human scale.

Volcanism is responsible for a highly distinctive class of landscapes, on which it acts both as a builder and a destroyer of geological and lithological features. Through geology and lithology, long after its paroxysmal phases, volcanism can affect flora and fauna in a specific network of ecosystem interactions, powerfully influencing the type, distribution, and availability of critical resources on which man relies.

During the past fifteen years, archaeologists working in active volcanic areas have explored with increasing interest the repercussions of volcanic catastrophes on ancient man and the human modes of reaction (e.g. Grayson *et al.*, 1979). An anthropological and ecological perspective has been brought to attacking the problem in some cases. The most informative studies have perhaps been done in Central America (e.g. Sheets, 1979). Partly because of its conspicuous and often dramatic effects, active volcanism has enjoyed widespread attention in traditional archaeological contexts, well exemplified by Pompeii or Akrotiri (Thera). What I will term « fossil » volcanism has clearly failed to elicit comparable attention.

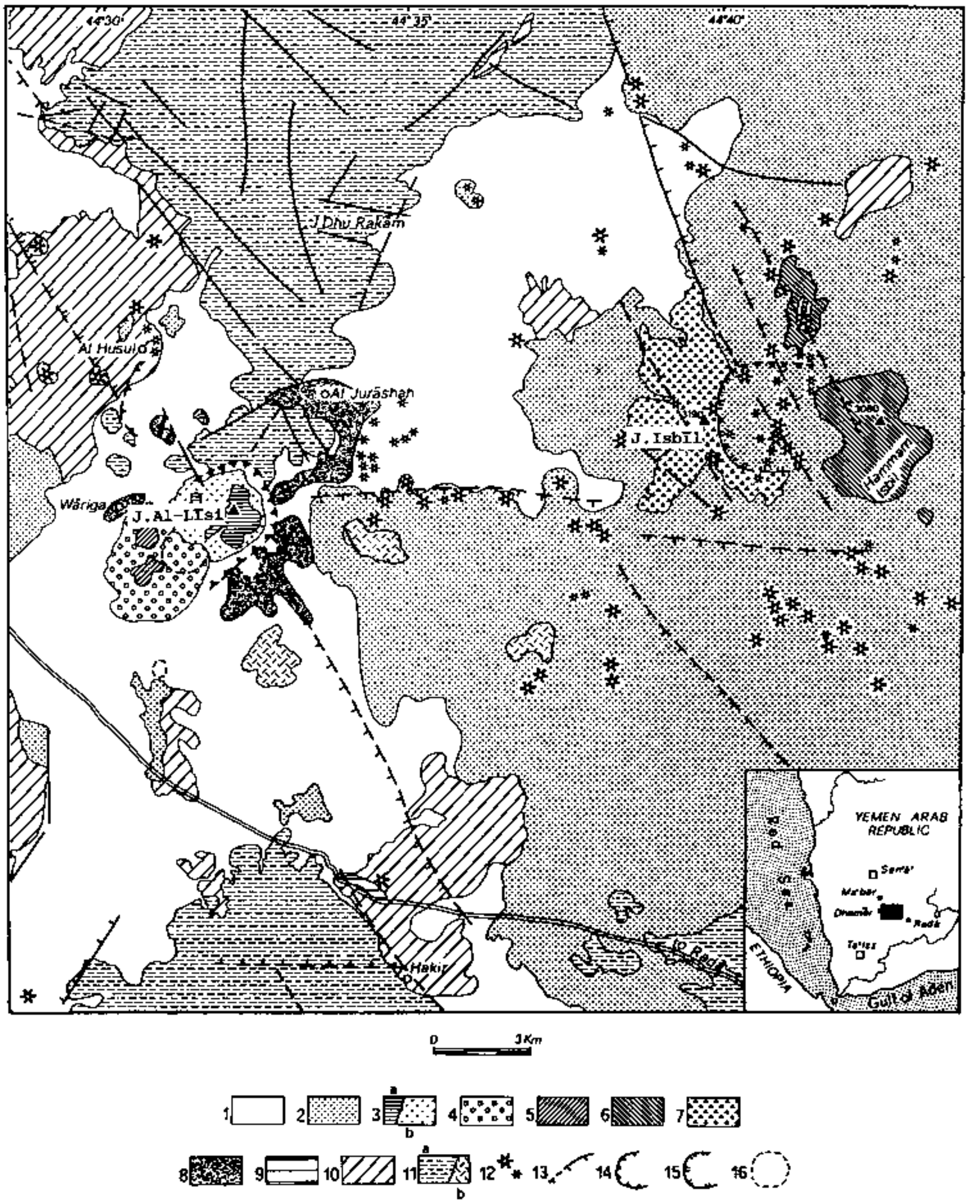

Fig. 1. Geological map of the Dhamār-Radā' volcanic field, North Yemen, including Jebel Isbīl and Jebel al-Lisī volcanoes. Adapted from Chiesa et al., *1983a. 1, recent sediments ; 2, recent basaltic volcanics ; 3, al-Lisī volcano (a = domical lava flows, b = pyroclastic deposits) ; 4, ash ring of al-Lisī volcano ; 5, lava domes SW of al-Lisī ; 6-7, Jebel Isbīl volcanic complex (6 = domical lava flows, 7 = Isbīl volcano) ; 8, Wāriga-Jurāshah tephra ; 9, Dhamār basalts ; 10, Dhamār ignimbrites ; 11, Trapp Series (a = lava flows and ignimbrites, b = felsic lava domes) ; 12, cinder cones ; 13, fractures and faults ; 14, presumed volcano-tectonic collapses ; 15, caldera rims ; 16, crater rims.*

Areas of fossil volcanism are here defined as territories characterized by widespread but long-dead magmatic activity. Such areas nevertheless provide human ecosystems with specific advantages and constraints. Moreover, volcanic activity imparts a static but indelible imprint on the landscape, a permanent signature with inherent constants and trends. As will be suggested, an ecosystem approach is especially suitable for analyzing the relationships between fossil volcanic landscapes and archaeology.

The North Yemen and ʿAsīr Highlands, which form the « backbone » relief of the southwestern Arabian Peninsula, are one of the largest areas of fossil volcanism in the world (Fig. 1). Endogenous and exogenous activities were linked in this region to the uplifting and faulting of the Red Sea Rift. In comparison with past volcanism, active volcanism is virtually negligible.

The climax of volcanism in Yemen dates from Oligocene-Miocene times, when an extensive sheet of basalts, rhyolites, and related igneous rocks of the so-called Trapp Series (Geukens, 1966) or Yemen Volcanics (Grolier *et al.*, 1978), was deposited over an area of about 40,000 square kilometres on the southwestern plateau (Chiesa *et al.*, 1983b). Smaller occurrences of the Trapp Series are known elsewhere in the Highlands.

Subsequent events are recorded up to about 10,000 years b.p., mainly in the Pleistocene. They include pyroclastic flow deposits fed by tectonic fissures, and central activity connected to the growth of volcano-tectonic structures and a few strato-volcanoes, notably Jebel al-Lisī (Fig. 2) and the imposing Jebel Isbīl in North Yemen, and Jebel al-Haylah in the ʿAsīr (Overstreet, 1973 ; Chiesa *et al.*, 1983a).

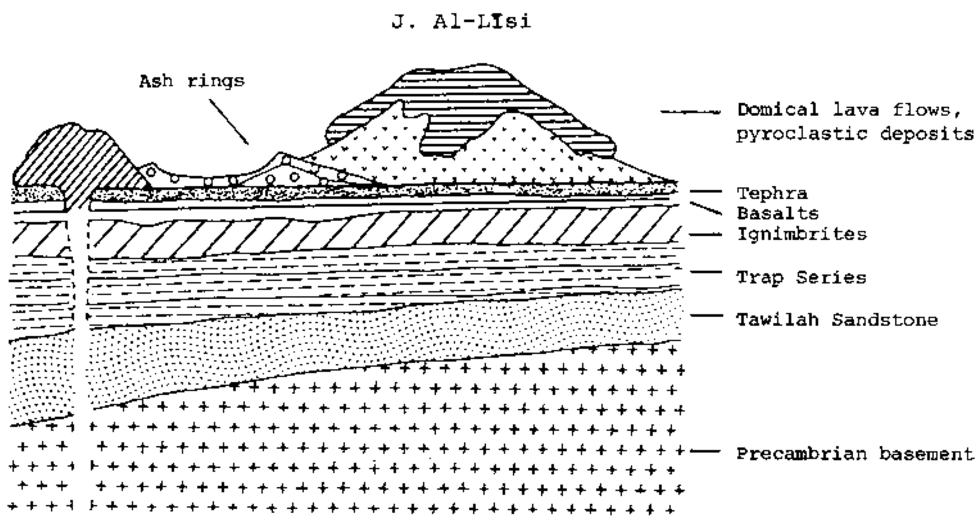

Fig. 2. Idealized section with Jebel al-Lisī volcano, illustrating the stratigraphic sequence of volcanic formations in the North Yemen Highlands. Adapted from Chiesa et al., *1983a. The Precambrian basement comprises a number of intrusive igneous units.*

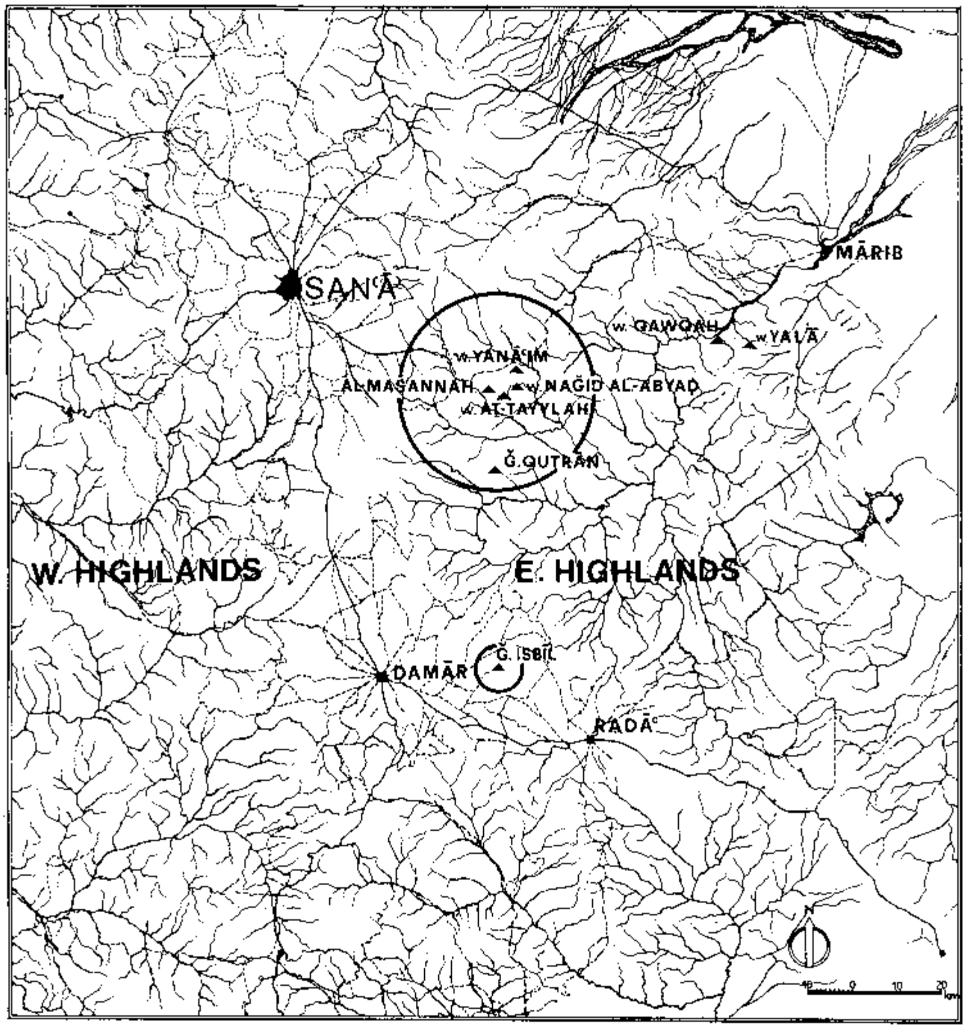

Fig. 3. Map of the central part of the North Yemen Highlands, emphasizing the drainage network ; desert margin to the NE beyond Mārib. Large circle = Italian study area as mentioned in this paper ; small circle = Jebel Isbīl volcano. Adapted from Italian Archaeological Mission original, 1988.

In addition to these Cenozoic formations, eastern Yemen as well as the whole interior of the Arabian Peninsula comprises an igneous and metamorphic rock complex or basement, the Arabian Shield (Grolier *et al.*, 1978). A different but extensive collection of volcanic rocks of Precambrian age is to be found in the Shield. « Volcanic » in this context is taken to include not only the effusive rocks but the associated intrusive units.

The fossil volcanic landscape of Yemen is indeed at its most extreme along the eastern border of the Highlands (Fig. 3), where the Cenozoic volcanic formations taper off onto the Precambrian granites and associated intrusive rocks of the Arabian Shield. Mesozoic sedimentary units only constitute limited interpositions. Thus the landscape in the eastern Highlands of Yemen is controlled by a rich intersection of different epochs and products of extinct volcanism. A large portion of the study area represented in fig. 3 (large circle) coincides with such a landscape.

2. *Human ecological analysis of man-volcanism relations*

The ecological analysis outlined in this paper is based on the concept of human ecosystem (cf. Butzer, 1983). I refer in particular to a static and simplified model of a human ecosystem such as the one represented in fig. 4 (Fedele, 1976), where the interdependent sets of human and natural entities

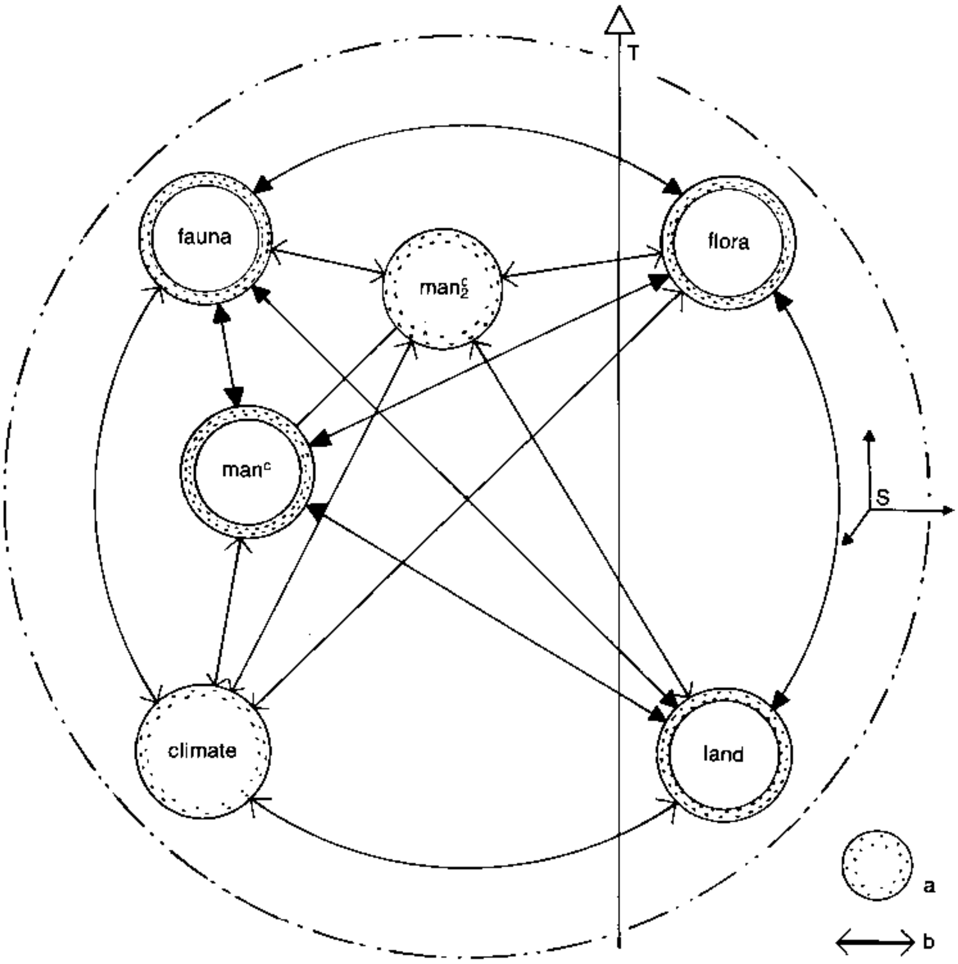

Fig. 4. The human ecosystem : a static and simplified model (see section 2 of text for details), emphasizing the important « components », a, and « interactions », b, in the discussion of fossil volcanic landscape. Adapted from Fedele, 1976.

are organized according to components (the circles in the diagram) and interactions (the double arrows).

The model presents a three-dimensional, entirely interconnected territory or « space », *s* ; the human, or more exactly the cultural, component in the system, subdivided into man^C (a given community) and $man^{C}2$, the effect of alien communities ; the organization of the non-human environment under four essential subsystems, *flora* and *fauna* (the biotic components) and *land* and *climate* (the abiotic components) ; the dynamic equilibrium between all these components, the overall interaction network represented by arrows ; and finally the time dimension, arrow *t*, implying a « diachronic » trajectory of the ecosystem.

In Yemen, volcanic imprint on the landscape can be analyzed according to the main ecosystem components which were affected, as is shown in table A. Landscape is equated with the perceived environment of man (*cf.* Fedele, 1982a), that is, a term with a strong cultural connotation. Another such term is resource, as used in the table.

The way man interacts with the environment is no less dictated by cultural meanings and perceptions than by the intrinsic characteristics of environmental components. The role of environmental perception is perhaps even greater for communities living in more extreme and limiting habitats, such as the fossil volcanic uplands of the tropical belt. This suggestion cannot be conveniently developed here.

Yemen lies within the arid zone of the northern hemisphere. Climate, however, does not appear to be a major player in volcanic ecosystems, as it is easily overshadowed by the behaviour of land and the biotic components (the « biome »). It is the only variable that is independent of volcanic imprint.

Table A offers a framework for the ecosystem analysis of man-volcanism relationships in the case of fossil volcanic landscapes. It is assumed that fossil volcanism effectively conditions critical resources on a permanent basis : but which ones, in what direction, and truly permanently ? An essential part of the discussion will be a search for constants through time, or at least for recurring processes and long-term trends which might characterize fossil volcanic landscapes.

A series of observations and predictions, based on currently available data from North Yemen, will be presented following the guidelines of the four environmental categories of table A.

3. Land : extractable resources

Volcanism is responsible for the obsidian deposits in the area of Jebel Isbīl, possibly the only important obsidian-bearing area in southern Arabia.

As elsewhere in the ancient Near East, this obsidian was sought, but, rather surprisingly, not as actively as one might have supposed. Whether it also became the object of long-distance distribution across southern Arabia is not yet clear.

In fact, preliminary examination by XR fluorescence analysis shows that Jebel Isbīl and Jebel al-Lisī were not the only sources of obsidian for ancient Yemen. « Statistical compositional analysis carried out on 116 archaeological obsidian samples revealed four different groupings, but only 20 samples ... can safely be stated to have been made with Jebel Isbīl obsidian » (Francaviglia, 1985).

Survey and excavation by the author in the eastern Yemen Highlands, particularly in the secluded and barren Wādī ath-Thayyilah drainage lying in the region of Precambrian granites (Fedele, 1986 ; 1988), suggest that local neolithic communities had access to some smaller sources of obsidian within a short distance. Large-sized obsidian artifacts from a new area to the north (1987 survey) seem to support this hypothesis.

In this case an interesting contrast could be expected between a major obsidian source and one or more lesser ones, located in different geographical districts. The archaeological relevance of such a pattern, with its overlapping distribution networks, would be both regional and theoretical. But the hypothesis is still unproved and only further research will tell.

The volcanic landscape in the region of Precambrian granites also provided fine-grained granites, mafic filonian rocks from swarms of dikes, and scattered outcrops of brightly coloured silicate or siliceous rocks from other igneous components. These too were understood as useful and exploited on a limited basis by the Thayyilah groups (de Maigret *et al.*, 1988). Large-scale excavation of a neolithic village in 1986 made it clear that hard, fine-grained granites were used for the manufacture of macrolithic and other heavy-duty tools (Fedele, 1986 ; and in de Maigret *et al.*, 1988).

By itself the volcanic region lacks other useful rock types. But existing resources were of such interest to man that they effectively supplemented the low-quality cherts and quartzites supplied by the *wādī* alluvium in a rather restricting environment.

It must also be mentioned that Cenozoic basalts, in various parts of Yemen, were considered a suitable medium for rock engraving, at least as early as the Sabaean kingdom of the 1st millennium B.C.

In terms of rock resources, fossil volcanic landscape was thus favourable to prehistoric man. Prospecting for such resources may indeed have been an important factor in acquainting Holocene settlers with the North Yemen uplands.

4. Land : large-scale features

Although active volcanism is largely extinct, the North Yemen volcanic district is still subject to post-volcanic manifestations (hot springs etc.) and some tectonic instability.

A case of the latter has been studied in the Najd al-Abyadh and adjoining Wādī ath-Thayyilah basins of the eastern Highlands (Fig. 3) (Marcolongo *et al.*, 1988). There it is clear that recent fault-controlled block movements have been responsible for a lowering of the water table and the collapse of agricultural fertility. This process must be post-neolithic, or perhaps post-2000 B.C. in age, according to archaeological evidence linked to a consistent series of ^{14}C dates (de Maigret, 1988 ; Fedele, 1988). It should be regarded as the main cause of biome depletion and human desertion of the area.

Although long-term climatic change towards aridity should not be ruled out entirely, geomorphological changes seem to have been the predominant factor for population shifts during the past several millennia throughout the eastern Highlands (Fedele, in press).

Prior to the latest neotectonic events, the soils in the Thayyilah and comparable basins seem to have been unusually favourable to farming, in spite of their patchy distribution. Their chemical composition resulted from a variety of intrusive, effusive, and distant sedimentary rocks, as well as from the organic decay of supported vegetation. The chemical contribution from the volcanic district may have been of greatest importance.

A remarkable characteristic of volcanism is that it injects potential nutrients into the environment. Their nature and long-term effects in specific ecological systems should of course be assessed in detail before any ecological conclusion is drawn. But on the whole, fossil volcanic landscapes do not seem to be incompatible with soil fertility ; the problem may rather be the uneven distribution of nutrient-rich soils, within the prevailing texture of barren rock and infertile land.

Favourable conditions of the Thayyilah kind in middle Holocene times may turn out to have existed here and there in the Highlands, possibly leading to a pattern of discrete « habitat cells » (see below) with direct clustering effects on human settlement.

But small-scale structural changes in the geometry of the basins were sufficient to alter the fragile balance on which such conditions depended (Fedele, in press). Another aspect I would like to stress is indeed the relative vulnerability of human ecosystems to even modest disturbances of tectonic origin, disturbances which are normally inherent in the geological behaviour of a volcanic region. Most vulnerable in my opinion are hydrologic resources on the human scale, and soil fertility.

5. Biome : extractable resources

Soil composition normally has a bearing on floral composition. To what extent, in the granitic basement regions of the eastern Highlands, the volcanic floral composition may be advantageous or constraining for human activity, is still hard to tell. The botany (Al-Hubaishi *et al.*, 1984) and especially ethnobotany of Yemen have still to be investigated in depth.

Fig. 5. Site WTHiii, Wādī ath-Thayyilah, eastern Highlands. A view of 1984 excavations with large-rock alignment in the background and the surface of the mid-Holocene « Thayyilah paleosol » exposed in the nearest part of the trench. North Yemen Neolithic. Photo F.G. Fedele/MAIRAY.

Above the level of individual species and their intrinsic merits for man, including their visual quality, our reconstructions of the Thayyilah area indicate that certain parts of the pediment slopes and *wādī* terraces were mantled with grass and scrub vegetation. A preliminary palynological test would suggest local humidity, as indicated by *Typha*, *Sphagnum* and *Calluna* species, but it is insufficient to demonstrate the local presence of conifer stands (Lentini, 1988), as anemophile pollen can travel long distances (Fedele, in press). The existence of sparse timber vegetation is conceivable, however.

This reconstruction applies to the Neolithic period of North Yemen, provisionally dated between the 6th and 4th millennia B.C., not only on the basis of soil and sediment evidence (Fig. 5), including a ^{14}C date on humic acids from the « Thayyilah paleosol » (5750 ± 500 b.p., calibrated to 5280-4000 B.C.), but also because of the importance of cattle pastoralism among those groups (Fedele, 1988 ; de Maigret *et al.*, 1988). Domestic cattle require suitably watered pasture, ideally within walking distance of the settlements (for habitat requirements of cattle *cf.* the discussion in Bintliff *et al.*, 1982, p. 139-43).

As mentioned in section 3, one of the villages was extensively tested by the author in 1984-86 (the *WTHiii* site ; Fedele, 1986). Such information may be a little outside the scope of this paper, but I wish to point out that, generally speaking, interesting relationships between the fossil volcanic environment and human culture, as mediated by the composition of the biotic resources, are to be expected and therefore investigated.

6. *Biome : biomass and distribution of resources*

Larger-scale biotic attributes of the environment are the biomass (i.e. the quantity of living matter per area unit, either global or seasonal) and spatial distribution of biotic resources. Both are an integral part of landscape or the perceived environment of man.

The constant trend of granitic-arkosic landscapes towards barrenness implies sparse tree vegetation, hence relatively low biomass values for tree- or woodland-loving species, such as browsers and certain birds. Biomass includes both plants and animals. Tropical grass-scrub ecosystems with sparse tree vegetation, such as those of the savanna, can on the other hand carry considerable populations of other species, with aridity as the main limiting factor for species variety and number of individuals.

It can perhaps be assumed that volcanic landscapes of the eastern Yemen Highlands type are conducive to low-density but locally concentrated biotic resources. The hypothesis can be made that there is a positive correlation between fossil volcanism and the clustering of biotic resources, via the discontinuous distribution of land characteristics (see section 4 above). Wādī ath-Thayyilah possibly represented for several millennia just such a « concentration » biotope. To what extent this may be a characteristic of fossil volcanic landscape, as divergent from — say — carbonate-dominated landscape, has still to be assessed and quantified.

My hypothesis is that, in fossil volcanic landscapes, critical resources for human settlement tend to be sparse rather than scarce. Plant and animal resources in particular tend to cluster unevenly and form compartments, or « concentration » biotopes, scattered among vast tracts of resourceless land. This is the case not only in Yemen, as a consequence of fossil volcanic environments, but elsewhere in the arid tropical belts (e.g. the Sahara ; *cf.* Clark, 1980 ; Fedele, 1982b). It is just possible that fossil volcanic conditions make the phenomenon more extreme.

Uneven clustering of critical resources, hence of settlement, leads to the corollary of human communities compartmentalized into « settlement cells », or « habitat cells ». Density and distribution of exploitable biotic resources can be assumed to have been a causal factor in the density and distribution of settlement.

Prehistoric antecedents of human nucleation may be emerging from our investigations in the Yemen Highlands. The hypothesis to be tested in North Yemen is whether, and to what extent, settlement concentration was causally correlated to the territorial effects that fossil volcanism had on biome. This correlation should be examined throughout the Holocene, during the advance of modern aridity as well as in the previous so-called Mid Holocene Pluvial. Case studies from other volcanic regions of the intertropical belt would be of value.

7. Some interim conclusions

In this paper the ecological concept of fossil volcanic landscape has been introduced. It is implicit that « fossil » and « active » volcanism are two intergrading polarities, rather than opposites, within a certain environmental continuum.

Fossil volcanic imprint on the land entails some permanent and obligatory characteristics, affecting the human ecosystems to both the advantage and disadvantage of preindustrial man. It is the balance of the two that conditions man's use of volcanic landscape. A parallel balance of some importance may exist between landscape constants and variables, or more exactly between what is ecologically « rigid » and what is « flexible » in the fossil volcanic landscape.

Examples from the North Yemen Highlands have been discussed, involving rock types and stone-working, soil fertility, tectonic and hydrologic instability, biomass characteristics, and the territorial patterning of critical resources.

Extreme clustering of biotic resources and hence a compartmentalizing of human settlement into widely spaced « habitat cells » is suggested as a significant correlate of fossil volcanic landscape, especially in the arid tropical zone.

The present outline is only a preliminary statement of observations, concepts, and hypotheses which form part of ongoing investigations.

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TABLE A. — SUGGESTED ENVIRONMENTAL COMPONENTS FOR ECOSYSTEM ANALYSIS OF MAN-VOLCANISM RELATIONSHIPS, AS APPLIED TO FOSSIL VOLCANIC LANDSCAPE (NORTH YEMEN).

1. LAND	1.1. EXTRACTABLE RESOURCES : rocks 1.2. LARGE-SCALE FEATURES : hydrology and soils
2. BIOME	2.1. EXTRACTABLE RESOURCES : individual species 2.2. BIOMASS AND DISTRIBUTION of biotic resources

REFERENCES

AL-HUBAISHI, A. and MÜLLER-HOHENSTEIN, K., 1984, *An Introduction to the Vegetation of Yemen. Ecological Basis, Floristic Composition, Human Influence*, Eschborn, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ).

BINTLIFF, J.L. and VAN ZEIST, W. (eds.), 1982, *Palaeoclimates, Palaeoenvironments and Human Communities in the Eastern Mediterranean Region in Later Prehistory*, Oxford, B.A.R.

BUTZER, K.W., 1983, *Archaeology as Human Ecology*, Cambridge, Cambridge University Press.

CHIESA, S., LA VOLPE, L., LIRER, L. and ORSI, G., 1983a, *Geology of the Dhamār-Radā Volcanic Field, Yemen Arab Republic*, in *N. Jahrbuch Geol. Paläontol. Mh.*, 1983 (8), p. 481-494.

CHIESA, S., LA VOLPE, L., LIRER, L. and ORSI, G., 1983b, *Geological and Structural Outline of Yemen Plateau : Yemen Arab Republic*, in *N. Jahrbuch Geol. Paläontol. Mh.*, 1983 (11), p. 641-656.

CLARK, J.D., 1980, *Human Populations and Cultural Adaptations in the Sahara and Nile during Prehistoric Times*, in *The Sahara and the Nile. Quaternary Environments and Prehistoric Occupation in Northern Africa*, M.A.J. WILLIAMS and H. FAURE (eds.), Rotterdam, A.A. Balkema, p. 527-582.

DE MAIGRET, A., 1988, *The Yemeni Bronze Age*, in *Yemen, 3000 Years of Art and Civilisation in Arabia Felix*, W. DAUM (ed.), Innsbruck, Pinguin-Verlag, and Frankfurt/Main, Umschau-Verlag, p. 38-40.

DE MAIGRET, A., FEDELE, F.G. and DI MARIO, F., 1988, *Lo Yemen prima del regno di Saba*, in *Le Scienze*, 40 (234), p. 12-23.

FEDELE, F.G., 1976, *Sediments as Palaeo-land Segments : the Excavation Side of Study*, in *Geoarchaeology, Earth Science and the Past*, D.A. DAVIDSON and M.L. SHACKLEY (eds.), London, G. Duckworth, p. 23-48.

FEDELE, F.G., 1982a, *Valcamonica : territorio e preistoria*, in *Il caso Valcamonica. Rapporto uomo-territorio nella dinamica della storia*, E. ANATI (ed.), Milan, Edizioni Unicopli, p. 101-140.

FEDELE, F.G., 1982b, *La successione culturale nel Teneré e nel Sahara*, in *Preistoria del Teneré (Sahara centrale). Storia e materiali della Collezione Turco*, F.G. FEDELE and G. TURCO, Bra, Museo Civico Craveri di Storia Naturale, p. 50-103.

FEDELE, F.G., 1986, *Excavations and Researches in the Eastern Highlands*, in *Archaeological Activities in the Yemen Arab Republic, 1986*, A. DE MAIGRET *et al.*, in *East and West*, 36, p. 396-400.

FEDELE, F.G., 1988, *North Yemen : the Neolithic*, in *Yemen, 3000 Years of Art and Civilisation in Arabia Felix*, W. DAUM (ed.), Innsbruck, Pinguin-Verlag, and Frankfurt/Main, Umschau-Verlag, p. 34-37.

FEDELE, F.G., in press, *Man, Land and Climate : Emerging Interactions from the Holocene of the Yemen Highlands*, in *Man's Role in the Shaping of the Eastern Mediterranean Landscape*, W. VAN ZEIST *et al.*, (eds.), Rotterdam, A.A. Balkema.

FRANCAVIGLIA, V., 1985, *In Search of the Ancient Arabian Obsidian Sources*, in *Archaeological Activities in the Yemen Arab Republic, 1985*, A. DE MAIGRET *et al.*, in *East and West*, n.s., 35, p. 373.

GEUKENS, F., 1966, *Geology of the Arabian Peninsula. Yemen*, U.S. Geological Survey Professional Paper 560-B, U.S. Geological Survey, Washington.

GRAYSON, D.K. and SHEETS, P.D., 1979, *Volcanic Disasters and the Archaeological Record*, in *Volcanic Activity and Human Ecology*, D.K. GRAYSON *et al.*, (eds.), London and New York, Academic Press, p. 623-632.

GROLIER, M.J. and OVERSTREET, W.C., 1978, *Geologic Map of the Yemen Arab Republic (San'ā')*, U.S. Geological Survey Miscellaneous Investigations Series, Map I-1143-B, U.S. Geological Survey, Washington.

LENTINI, A., 1988, *Preliminary Pollen Analysis of Paleosoil Horizon in the Yalā Area*, in *The Sabaean Archaeological Complex in the Wādī Yalā (Eastern Hawlān at-Tiyāl, Y.A.R.) : a Preliminary Report*, A. DE MAIGRET (ed.), Rome, ISMEO, p. 52-53.

MARCOLONGO, B. and PALMIERI, A.M., 1988, *Environmental Modification and Settlement Conditions in the Yalā Areā*, in *The Sabaean Archaeological Complex in the Wādī Yalā (Eastern Hawlān at-Tiyāl, Y.A.R.) : a Preliminary Report*, A. DE MAIGRET (ed.), Rome, ISMEO, p. 45-51.

OVERSTREET, W.C., 1973, *Contributions to the Prehistory of Saudi Arabia*, vol. 1, Coconut Grove (Miami), Field Research Projects.

SHEETS, P.D., 1979, *Maya Recovery from Volcanic Disasters : Ilopango and Cerén*, in *Archaeology*, 32 (3), p. 32-42.