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RISE AND FALL OF AXUM, ETHIOPIA: A GEO-ARCHAEOLOGICAL INTERPRETATION

Karl W. Butzer

Civilizations represent human ecosystems amenable to systematic geo-archaeological analysis. The civilization of Axum, spanning the first millennium A.D., had its settlement core on the now-denuded, subhumid plateau of northern Ethiopia. Axum, a new city, began A.D. 100 as a ceremonial center, growing to over 10,000 people, as a prosperous emporium for international trade. Intensified land use led to mass movements in slope soils before A.D. 300, but a range of clayey stream deposits also implicates strong periodic floods and seasonally abundant moisture. The paleoclimatic ensemble suggests that stronger and more reliable spring rains allowed two crops yearly without irrigation, compared to only one with modern summer rains. Trade declined after 600 and Axum was essentially landlocked by 715. Intense land pressure and more erratic rainfall favored soil destruction and ecological degradation during the seventh and eighth centuries. Largely abandoned by 800 and pillaged by border tribes, Axum retained only symbolic significance as power shifted to the more fertile lands of humid central Ethiopia. Axum shows how the spatial and temporal variability of resources, and the interactions between a society and its resource base, can be fundamental in the analysis of historical process.

ARCHAEOLOGICAL SITES ARE part of landscapes that once were an integral part of a human ecosystem (Butzer 1979b). Most archaeologists continue to take a static, classificatory approach to environmental variables, regarding the biophysical landscape as a spatial and temporal backdrop. Contemporary geo-archaeological research is therefore increasingly committed to investigation of interactions and potential readjustments among the human and nonhuman components of the environmental system, in response to both internal processes and external inputs (Butzer 1979a). The primary goal is more than the elucidation of a site-specific archeo-sedimentary system: it is the study of sites as part of a complex human ecosystem, within which communities once interacted spatially, economically, and socially.

At a more comprehensive scale (see Butzer 1978), civilizations can be viewed as an adaptive system, characterized by community behavior that reflects the inhabitants' perceptions of the biophysical environment and which adjusts in response to internal and external changes (Butzer 1980c). One of the fundamental components of such an adaptive system is its productivity. This includes primary, agricultural productivity as well as the secondary productivity of either vertical exchange systems within the society or horizontal exchange systems maintained with neighboring societies. A second component, resources, can be seen as a set of opportunities available in the environment and subject to spatial and temporal variability. Spatial variables include the unequal, patterned or irregular, concentrated or dispersed nature of resources—whether of food, raw materials or finished products—and the critical matter of access to such resources. Temporal variables include seasonal regularities, aperiodic fluctuations or long-term changes of the environmental determinants, the issue of sustained productivity versus temporary or cumulative exhaustion, and the impact of subsistence shifts, technology, and transformations of related exchange networks.

Such theoretical arguments are best illustrated by concrete examples. Elsewhere, I have already attempted to show that the Egyptian adaptive system, linked to a floodplain ecosystem, was repeatedly subject to significant inputs as a result of Nile flood variation: agricultural productivity fluctuated dramatically, with direct demographic impact and—in chance combinations with social pathologies, poor leadership or external political stress—contributed to sociopolitical

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transformations in Egyptian civilization (Butzer 1980c, 1980d). Another, different example of such complex, reciprocal relationships is provided by Axum, an early literate civilization that flourished in northern Ethiopia during the first millennium A.D.

THE AXUMITE EXCHANGE NETWORK

Axum was the only subsaharan African kingdom known to the literati of the classical world. The port of Adulis (modern Zula), on the Eritrean coast of Ethiopia, was probably linked to Mediterranean commerce as early as the reign of Ptolemy Euergetes I (247–222 B.C.). By A.D. 300 a powerful kingdom had emerged around the Red Sea, temporarily controlling much of northern Ethiopia, the Sudan, and South Arabia (Littmann 1913; Conti-Rossini 1928; Doresse 1957; Pankhurst 1961; Kirwan 1972a, 1972b; Sergew 1972; Kobishchanov 1979). The mercantile and political sophistication of this kingdom, centered at Axum, can be inferred from the fact that coins of the Hellenistic type were struck here from the late third to the early eighth centuries.

The conventional view is that Axumite culture owes its origin to a graft of Arabian institutions and technology on to East African roots. The basic traits attributed to South Arabia are writing, religious and political symbolism, architectural and irrigation technology, Near Eastern cultigens such as wheat and barley, and possibly the plow—although the Semitic language may considerably antedate the archaeological evidence of Arabian influences in northernmost Ethiopia ca. 600–200 B.C. (Anfray 1972a, 1972b; Levine 1974; Clark 1976; Kobishchanov 1979; J. W. Michels, personal communication 1977). The critical East African traits are thought to have been cattle pastoralism and the cultivation of a variety of indigenous plants (including the grain teff [*Eragrostis*], the oilseed *nug*, and the false banana [*Musa ensete*], see Harlan 1971).

Whatever the antecedents, the Axumite core area emerged on the subhumid northern periphery of the Abyssinian Plateau, in a region delimited archaeologically in Figure 1. The direct record indicates grain-farming, with the aid of iron-tipped, oxen-drawn plows; bronze, wood-hafted sickles; and piedmont flow-irrigation from cisterns. Large herds of long- and short-horn cattle, sheep and goats, camels and unidentified pack animals (mules and donkeys?) provided meat, milk, hides, or transport. A well-developed local metallurgy (iron, bronze, copper) depended on both local and imported ores, and required abundant local firewood or charcoal.

The rise to power of the Axumite Kingdom after A.D. 100 was intimately linked with the role of Adulis, and later Axum, as a gateway city (Hirth 1978) that funneled diverse resources from the continental hinterland of the Abyssinian Plateau and the Sudanese plains into a maritime exchange network which netted commodities from as far afield as India, China, the Black Sea, and Spain (Kobishchanov 1979:175ff.). Already the Fifth Dynasty pharaohs (ca. 2541–2407 B.C.) obtained gold and dark tropical timbers ("ebony") from inland areas south and east of the Red Sea (Kitchen 1971). In the first and third centuries A.D., both Pliny (VI:173) and the *Periplus of the Erythraean Sea* (Schoff 1912:23) specify ivory, rhinoceros horn, hippopotamus hides, and slaves as exports from Adulis. Later, large-tusked elephants or ivory, together with gold dust and hides, were shipped out from Axum via Adulis; this on the basis of firsthand accounts by two Byzantine travellers, Nonnus (ca. A.D. 526–530) (Kobishchanov 1979:104–105, 265) and Cosmas (ca. A.D. 525) (Wolska-Conus 1968). In addition, Axum controlled the frankincense trade for part of this time. Although specific source areas referred to by the *Periplus* and Cosmas were Somalia and South Arabia, the surviving incense trees (*Boswellia papyrifera*) along the steep edges of the northern Abyssinian Plateau now number 32 million, capable of producing up to 5,000 tons annually (Wilson 1977). The nonperishable exports of Adulis and Axum in classical times are almost identical to those of early nineteenth-century Massawa (Figure 1): slaves, gold, ivory and civet cat musk (Pankhurst 1968:370). Indeed, even civet itself may have been exported, since such extract has been identified from a probable perfume vial at Axum (Endt 1977).

Axumite exports, particularly elephants, were partly derived from the settlement core, and Nonnus reports:

> an unusual phenomenon (at Aua, probably Yeha); this was a multitude of elephants, about 5,000. They were pastured on a broad field. None of the natives was allowed to come close to them or to drive them from the pasture [Kobishchanov 1979:170].

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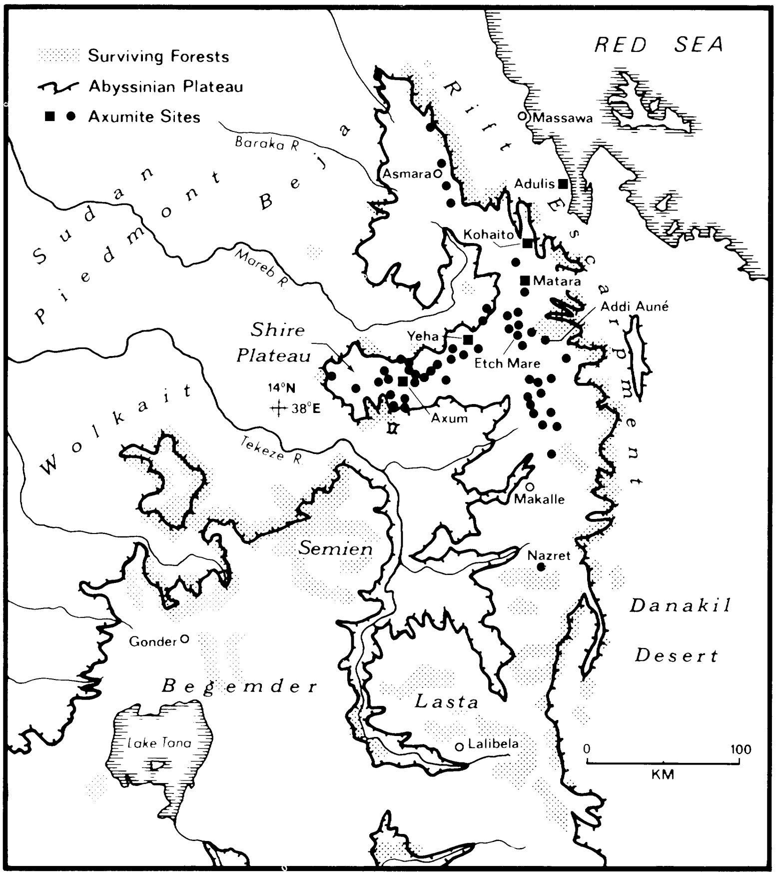

Figure 1. Northern Ethiopia, showing Abyssinian Plateau and surviving forests, as mapped from LANDSAT photography. Axumite sites after Anfray (1970), Fattovich (1977), Godet (1977), and Michels (1979).

Although a large herd of elephants would be notable on the denuded northern plateau today, elephants were still hunted in the surviving upland forests as late as the 1870s, their tusks exported to Massawa by caravan (Pankhurst 1968:248; Crawford 1958:177). Slaves, rhinoceros horn, and civet were, however, traditionally obtained from the interior uplands (Pankhurst 1961:372ff., 1968). Gold dust was panned in different parts of the plateau foothills, but came mainly from the Sudanese borderland, south of the Blue Nile (Pankhurst 1968:235ff.; Mohr 1971:236), as already described by Cosmas. In Axumite times these commodities were generally obtained by trade, in exchange for cattle, salt and iron (see Cosmas in Wolska-Conus 1968). As late as the nineteenth century, salt bars from the sea coast or the Danakil Desert were funneled through Makallé into the interior uplands and the Sudan and held exchange value as a prized commodity (Pankhurst 1968:240ff., 460ff.; Wilson 1976), while iron bars, probably from north Ethiopian sources (Mohr 1971:236), served as another form of currency (Pankhurst 1961:265, 1968:465).

From the fourth to the sixth centuries Axum was the commercial and administrative center of a kingdom that controlled the access to resources in much of Arabia and Africa, and which persistently maintained close ties with the Eastern Roman Empire. However, the primary productivity as well as the demographic base of the settlement core remained finite, while its role as a leading entrepôt in the classical world was conditional upon both the demand of foreign markets for its luxury goods and *pax in maribus*.

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THE ENVIRONMENT OF AXUM

The Axum countryside forms part of the plateau of Shiré (Troll 1970), a rolling upland at 2,100–2,400 m elevation, rising 500 m or so above the rugged valley system of the Mareb and Tekezé rivers. It represents a Mesozoic plantation surface, cut across complex Precambrian rocks or patches of Triassic sandstones (Mohr and Rogers 1966; Kazmin 1972). More resistant granites form dome-shaped or sugarloaf inselbergs on this surface, once mantled by thick Tertiary basalts and phonolitic lavas (Merla and Minucci 1938). The favored quarry stone for the key monuments at Axum is the local "granite," specifically, a fine-grained, nepheline syenite.

The town of Axum is situated along the southern piedmont of a group of syenite plugs, where a small drainage system (about 4 km^2) emerges among the hills to disperse onto a 3 km-broad, 8 km-long west-east depression (Figure 2). Local footslopes have average inclinations of 2–5°, set off from steep midslopes of 22–45°. Both concave and convex changes of slope in the syenite tend to be smooth and rounded, with some evidence of large-scale exfoliation.

The strong lithologic and topographic variation is reflected in a mosaic of soils similar to that studied in detail from igneous rocks around Makallé by Virgo and Munro (1978); Hunting Technical Services (1976:annex 1). The syenites are deeply kaolinized and altered to a white, yellowish, or reddish color. Hilltops preserve thin mantles of corresponding soils, with silt loam or clay loam textures. Much bare rock is exposed on the steep hillsides, where soil is limited to reddish, stoney sandy loams (*lithosols*), preserved in hollows and pockets. The flat plain below the town is floored by dark gray, montmorillonitic silt clays with prismatic structure. These heavy valley soils are typical swelling *vertisols*, that differ conspicuously from the reddish, kaolinitic *cambisols* on syenite parent material. Traditional Ethiopian agriculture does not utilize manure, but vertisols may allow continuous cultivation for up to 12 years, compared with no more than 4 or 5 years without fallow for the cambisols (Simoons 1960a:64–65). Unfortunately, no specific regional information is available.

Modern settlements are concentrated along lower hillslopes, with the most intensive cultivation on piedmonts or extensive areas of level, high ground. Terracing is not practiced, although the generally large and irregular plots are afforded some protection from erosion by stepped stone walls. Yet most groups of hills are ringed by multiple alluvial fans, formed of reddish soil products that spill over onto the edge of the vertisolic plains. These fans are dissected by temporary streams, with local evidence for two periods of cutting, producing broad, sandy channels that are now being attacked by narrow, single-branch or subparallel gullies. Even the vertisolic flats are rilled by discontinuous gully networks that, once formed, seem to be perpetuated as animal waterholes.

This pattern of advanced soil erosion in Shiré can be observed in detail around Axum. Slopes steeper than 15–18° expose large expanses of bare rock. Aprons and tongues of stoney soil wash rest on the lower slopes, covering many Axumite structures and exposing complex bodies of cobbles, gravelly silts, or fine soil in stream banks. Cultivation extends up from the 1–2° toeslopes along the edge of the clay plain to inclinations of as much as 12–15°, and then resumes on the domed, gently sloping, 4–8° hilltops. Sheetwash is conspicuous along the crests and midslopes, gullying on the footslopes. Nowhere does a complete mat of vegetation provide effective protection for the soil.

The modern vegetation of Shiré is designated as "montane savanna" (UNESCO 1958). In spontaneous form it is characterized by medium-height grasses, abundant perennial herbs, with local shrub thickets or dispersed medium-height trees (various acacias, the African olive, *Echinops, Gymnosporia*) (Picchi-Sermolli 1957:66ff.). But this open vegetation appears to be a result of prolonged and intensive human disturbance. Troll and Schottenloher (1939) described forests of *Acacia albida, Croton macrostachys, Ficus* cf. *sycomorus*, and *Cordia abyssinica* from secluded hollows, and cited these relict stands, as well as the scarcity of succulents, in favor of a relatively moist habitat. This is confirmed by the abundance of weedy plants, such as *Rumex*, in the ground cover, as well as by the thriving groves of planted Australian eucalyptus. Similar testimony is provided by the luxuriant groves of cedar (*Juniperus procera*), *Cordia*, fig, *Berebera ferruginea*, reeds and false banana last seen at Axum in 1861 by Heuglin (1868):147ff.) and Steudner (1862), although even then the hillslopes and uplands were denuded. A systematic evaluation of LANDSAT false-

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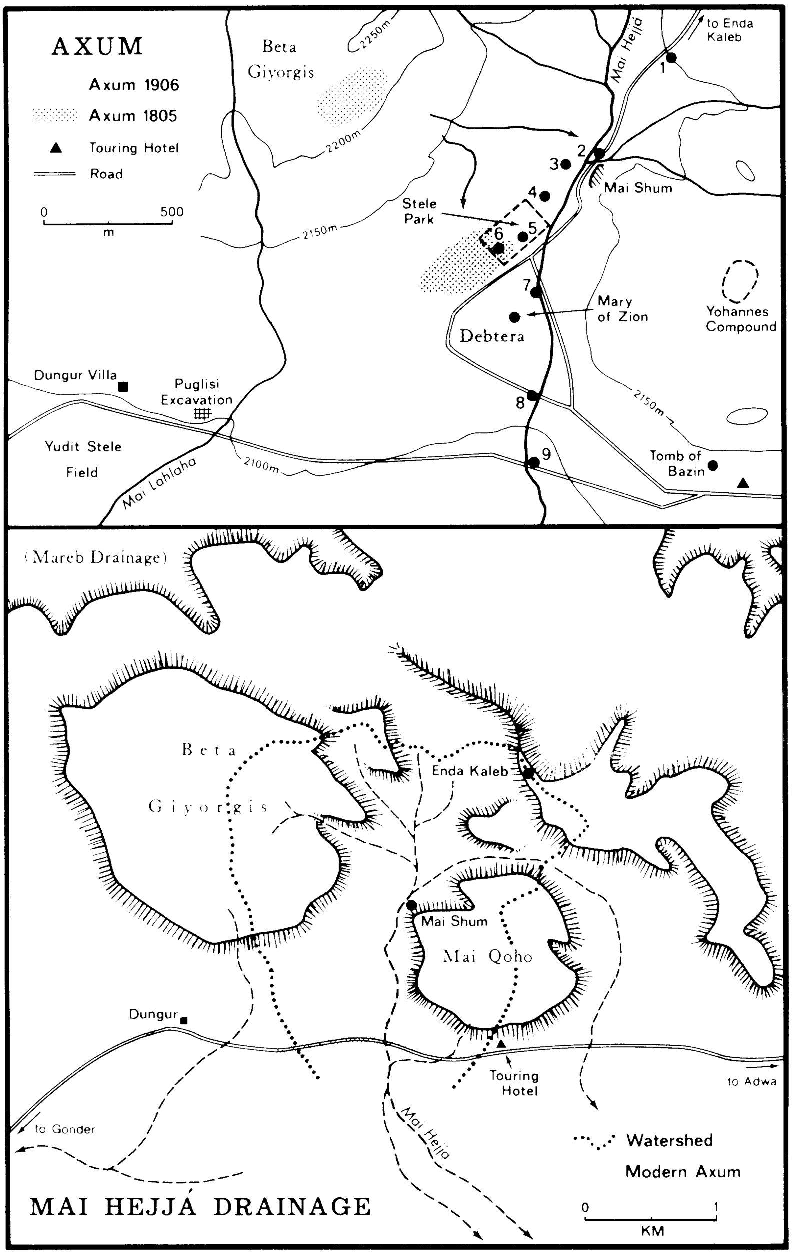

Figure 2. Axum (above) and the Mai Hejjá drainage (below): (a) Axum topography based on Chittick (1974:Figure 1), 1805 town after H. Salt (Mountnorris 1809, III:82), 1906 town after Lüpke (Littmann 1913:Plate 2). Points 1, 2, and 7–9 refer to sections discussed in text; 3 and 4, Enda Negus and Iyasus; 5, giant obelisk; 6, False Door Tomb; (b) Mai Hejjá watershed and form outlines after U.S. Air Force air photos 2176 and 2177; courtesy of Ethiopian Cartographic and Mapping Institute.

color composite imagery showed that woodland is still widely preserved along the thinly settled margins of the plateau (see also Hunting Technical Services 1976:annex 1; Wilson 1977). The principal areas of such woodland and scrub forest are shown slightly simplified in Figure 1.

The recent network of medium-length climatic records (Godani Tuni, personal communication 1973; Hunting Technical Services 1976:annex 2) suggests an annual rainfall of 600–800 mm for Shiré. Statistically, there are 3 1/2 rainy months (mid-June through September), although un-

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predictable spring rains (between mid-March and mid-May) may appreciably extend the wet season (Suzuki 1967). Variability of the summer rains from year to year also is considerable, and annual totals vary from 56% to 183% of the mean. Annual temperature ranges are minimal (3°C), diurnal ranges great, with a mean temperature near 18°C. This is a monsoonal, upland savanna climate (*Cwig* in the Koeppen system). A similar classification applies to all the plateau areas with Axumite settlement, but there are substantial differences in detail: upland rainfall increases from less than 450 mm (2-month rainy season) in the far north, to over 900 mm (6-month rainy season) in the south, with rains heaviest and most persistent along the high Rift Escarpment (Flohn 1965; Troll 1970; Griffiths 1971; Hunting Technical Services 1976:annex 2).

Given the macroclimatic parameters, the nature of the relict vegetation, and the soil mosaic, African analogs suggest that the original, "natural" plant cover was an open, mainly deciduous woodland on well-drained ground, more scrubby on steep rocky slopes, and with evergreen elements such as cedars, figs, and palms concentrated near streams and spring seeps; the poorly drained flats probably remained grassy. This projected picture of vegetation prior to the earliest agricultural settlement of Shiré implies subsequent degradation of the plant cover in general, and almost total deforestation of the piedmonts and hilltops.

A GEO-ARCHAEOLOGICAL STRATEGY TO STUDY ENVIRONMENTAL DEGRADATION

The contemporary landscape appears to be vastly inferior to that which provided the resource base for the Axumite kingdom. Water is scarce, runoff and stream discharge are temporary, slope and upland soils are thin, and the vegetation is evidently degraded. Questions can be raised whether this picture reflects transformations which occurred during the last century or so, or modifications during or immediately after the heyday of Axum. Was the environment more productive in Axumite times? Have climate and environment changed since? Such questions have never been formulated for Axum, let alone answered. Recent deforestation and soil erosion have been discussed for several parts of upland Ethiopia, but the historical problem remains unexplored. Two basic issues can be isolated: climatic change and environmental degradation.

The catastrophic impacts of the drought of 1971–1974 illustrate the sensitivity of the Ethiopian productive sector and even of national institutions to rainfall variability. The "little rains" of March through May failed completely, and the "big rains" were severely curtailed. The effects were particularly severe in the marginal, subhumid environment of northern Ethiopia, where the countryside was largely brown even at the end of the "big rains," as in September of 1973. Unlike the central and southern uplands of Ethiopia, where two or even three crops can be planted annually on a single plot, the northern plateau generally allows only one harvest per year on unirrigated land. As the rainfall season lengthens southward, two crops are the norm, beginning about 50 km south of Makallé, in the Nazret area of Figure 1 (Hunting Technical Services 1976:annex 4). Further north, soil moisture is adequate for crop growth only between mid-June and November or early December, when grains and legumes are harvested. Locally, on the better cambisols, some lands may already be planted in April, whereas many of the heavy, seasonally flooded vertisols are seeded only in September, after the rains (Hunting Technical Services 1976:annex 1, 4). Soil type is critical because the impermeable vertisols require an extra month to absorb sufficient moisture for crop growth (Virgo and Munro 1978).

There are regional indicators that the first millennium climate was different. So, for example, in the Danakil Desert, the now-dry Gobi graben held a 50-m deep lake dated 25 B.C., while Lake Gamari was 1.5 m deeper than now, with dates of A.D. 675 and 930 (Gasse et al. 1974: 1960 ± 160, 1300 ± 120 and 1030 ± 100 years, M-127B, 104 and 108; calibrated by the charts of Damon et al. 1974). Nile flood levels, reflecting on the Blue Nile and Atbara drainage of Ethiopia, provide another climatic index. In Nubia the floods began a long-term rise early in the Christian era, with episodic, destructive floods between about A.D. 600 and 1000 (Adams 1965). The gauge readings of the Nile at Cairo, beginning in 622, are more precise: floods were generally high until 760, followed by a negative trend, and then abnormally low levels 930–1080; however, low water levels partly related to the spring rains of northern Ethiopia, already averaged below normal 730–805 (Bell and Menzel 1972; also Hassan, n.d.). However, Lake Rudolf, reflecting rainfall

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trends over southwestern Ethiopia, was relatively low throughout this period (Butzer 1971, 1980b). There is, then, evidence for a relatively moist period, limited to the Blue Nile-Atbara and Awash drainage of northern and central Ethiopia, from before A.D. 1 to about 730, followed by a period of highly erratic rainfall, and then by generally dry conditions after A.D. 930.

A royal inscription of ca. A.D. 300, recorded by Cosmas in Adulis, appears significant in this context:

> I waged war on . . . the people of Samen (Semien) who live across the Nile (Tekezé) in inaccessible and snowbound mountains where storms and icy cold persist and the snowfall is so deep that a man sinks in it up to his knees [Kirwan 1972a:172].

Nineteenth-century travellers' reports on snow in the Semien (to 4,623 m) all refer to elevations above 3,600 m and mainly relate to spring and summer, although in at least three years (1807, 1841, 1881) snow persisted through most or all of the dry, winter season (Simoons 1960b). However, there is no evidence for Holocene glaciation (Hastenrath 1974), and Cosmas's secondhand report does not prove a period of cooler climate in northern Ethiopia. But Cosmas serves to draw attention to the elusive March-to-May "little rains" of Axum that may bring snowstorms to Semien. These spring rains are linked to aberrant, upper air troughs or cutoff lows in the westerly circulation (see Flohn 1965).

The Sabean predecessors of the Axumites introduced irrigation from South Arabia, and there are traces of irrigation dams or water storage basins at Axum, Kohaito, Matara, Etch Maré and Addi Auné (Krencker 1913:141, 148–152; Anfray 1973). In 1520 Alvares explicitly describes elaborate water control at Yeha, noting that fields are "all irrigated by channels of water" descending from the mountains and "made with stone" (Beckingham and Huntingford 1961:141). Given the basic hydrology of the Axum watershed, and others like it in Shiré, the potential water supply is severely limited, given modern rainfall patterns, even where supplementary irrigation is possible. Several centuries of cooler and wetter spring weather would not only have a major impact on hydrology, but would improve productivity of the vertisolic lowlands, extend the growing season from 5 to 7 or even 9 months, and allow two crops annually on cambisols or, with some irrigation, also on vertisols.

Although the Nile and Danakil records, interpreted in the light of the Semien snows, provide a tempting paleoclimatic framework, specific local evidence from Shiré is indispensable to make a case.

The second basic question can also only be resolved by site-specific research. The degraded vegetation of Shiré is striking in its own right, but biotic communities may recover to some degree when human pressure is reduced, and vegetation histories when investigated by paleobotanical methods are inevitably complex. Since pollen and plant macroremains have not yet been recovered from historical sites in Ethiopia, surrogate evidence must be used. Critical here is the hydrological cycle, which reflects ground cover, soil infiltration, and runoff, and which potentially leaves an informative record of interference in the biophysical environment. Disturbed or truncated soil profiles, redeposited soils, alluvial fills, or erosional gullies can, in archaeologically controlled situations, allow identification of human intervention as much as human constructs can.

Comprehensive geo-archaeological assessment of the cumulative, direct and indirect impact of human land use is potentially most productive in and around major occupation sites. Abandoned living quarters or ceremonial areas rapidly accumulate refuse and rubble, even prior to collapse, through human agency, gravity, or rainwash. Eventually, gradual or sudden roof and wall collapse will create large masses of structural rubble, such as stone, fired brick, mud brick, adobe, wood, and other fibers. Then, rainwash, soil creep, and slumping erode the site, progressively reducing its slopes and spreading surficial sediment from the center to the peripheries. An extensive apron of rainwash (colluvium) and stream-laid fills (alluvium) is spread out far from the former site, with artifactual material serving both as an index of indirect human agency and as a valuable stratigraphic aid. In combination with buried or truncated soils, such archaeological sediments can provide spatial and temporal perspectives on human intervention.

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Microstratigraphic evaluation of archaeosedimentary columns both inside and outside of the site can be sensitive to internal (cultural) or external (biophysical) events through direct and indirect, comparative interpretation. With a sufficient number of detailed, microstratigraphic sequences it may, in fact, be possible to filter out the excessive detail of what may have been no more than stochastic, cultural processes within a single occupation phase. The "screened" record could then provide a broader, spatio-temporal framework for cultural impacts or climatic oscillations or both.

The basic research strategy for investigating Axum was devised after a general evaluation of the site area during a visit in 1971. Subsequently, in 1973, profiles were studied in a range of excavated sections and natural exposures—within the former center of Axum, along the length of the local stream and, on a transverse axis, along the piedmonts on either side of town. Sediment and soil samples were then studied in the laboratory. Additional sections and samples were kindly provided by H. N. Chittick, who excavated at Axum 1973–1974. The resulting data provided a strong empirical basis for reevaluation of the available body of archaeological and historical information. A further field season was considered to extend this study to other, key Axumite sites, but these plans had to be abandoned in view of the political devolution after 1974. Consequently, this paper is intended to serve as an interim, rather than comprehensive analysis of the reciprocal relationships between the Axumites and their biophysical environment. The geoarchaeological data base is first presented in summary form, but with sufficient detail to support the far-reaching implications explicated in the subsequent sections of this paper. These site-specific details also illustrate a new methodology.

THE GEO-ARCHAEOLOGICAL DATA BASE

Enda Kaleb. In the headwaters of the catchment, a low ridge separates the gorges of the Mareb drainage from the gentle incline of the valley of Axum, the Mai Hejjá (known as the Mai Malahsó upstream and Mai Mataré further downstream; *Mai* is archaic Ge'ez for "water"). Soil and architectural debris cover tombs of Kaleb (A.D. 514–543) and Gabra Masqual (ca. 550–580), actually a church superstructure incorporating subterranean components of the pre-Christian age (Chittick 1974), i.e., Early Axumite and predating A.D. 350. Superficial rubble extends from the 5° footslope across the site with variable dips of 2–5°. Two sedimentary units can be recognized.

The younger unit is 50–100 cm thick, in part representing back-dirt from the German excavations of 1906. This material is a crude rubble in a matrix of humic, yellowish brown (Munsell color hue: 10 YR) loam (USDA textural classification, all textures based on hydrometer and wet-sieve analyses). The rubble, comprising local bedrock, building stone, and potsherds, is crudely to poorly stratified, while sorting according to size is minimal (as in almost all other soils and sediments analyzed). It is a mixture of structural collapse and reworked soil components, subsequently altered by pedogenesis.

The older sediment is more than 125 cm thick, covering or embanked against the foundations of the Kaleb complex. Stratification of this strong brown (7.6 YR), clay loam is prominent, with some dispersed rubble and linear concentrations of finer gravel. The bedding, limited quantity of building stone, and slightly improved sorting indicate a water-laid soil wash deposited across the length of the footslope after completion of the superstructure, but prior to its collapse. A *terminus post quem* is given by an amphora neck dating between the fifth and early seventh centuries (Chittick 1974). If the church was destroyed during the unsettled eighth to tenth centuries, it follows that sheet erosion was active in the interim, and that Enda Kaleb was neglected and the floor already buried by soil wash a meter and more thick.

The Upper Mai Hejjá Floodplain. A 2-m gully intersects a high-lying alluvial fill on the road to Enda Kaleb, 550 m north of Mai Shum (Figure 3a; Figure 2:Site 1). Resting on white, kaolinized bedrock is a truncated, 50-cm horizon of coarse prismatic, dark gray (5 Y 4/1), clay loam. This is an intact vertisol, once representative of local valley soils.

On top of this cracking clay are 30–100 cm of reworked vertisolic material, mixed with considerable sand, dispersed subangular gravel and cobbles, as well as occasional boulders. The

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poor stratification, heterogeneous calibration, and irregular basal and upper contacts all suggest relatively rapid slope sludging that involved mass movements.

This inhomogeneous loam is overlain by 50–250 cm of weakly stratified, brown (10 YR) sandy loam. Sands are rich in unweathered feldspars, unlike the basal clay, indicating fresh erosion of a partly weathered C-horizon further upslope. The limited rubble, other than that littering the surface, argues for gradual accumulation, with a moderately effective mat of vegetation, probably by sheet wash and soil creep.

The confluence just north of Mai Shum exposes two different valley-floor sediments (Figure 3b; Figure 2:2). At least 2 m of dark loam, with lenses of coarse gravel, represent more reworked vertisolic sediment. Embanked disconformably against this is a brown loamy sand, with dispersed pebbles and cobbles. This younger fill can be followed up both stream arms as a + 2-m alluvial terrace; downstream it thickens rapidly.

Near Mai Shum this + 2-m alluvial terrace increases from a relative elevation of + 2.5 to + 3.5 m, and exhibits three facies (Figure 3c): a body of subrounded, cobble to boulder-grade gravel giving way to well-stratified brown, sandy loam, interbedded with subangular, coarse to cobble-grade gravel, and covered by a brown loam, stratified near the base but vertically structured at the top. The crude detritus derives from small, steep, west-bank tributaries and the facies are to some degree time-transgressive. However, there is a valid temporal sequence from coarse to fine, and from laterally aggrading, coarse alluvial fans to a general, finer-grade longitudinal valley alluviation.

Of considerable interest is an apparent, breached earth dam 50 m downstream of Mai Shum. This feature does not affect the basic terrace gradient, and may have been constructed during or even after the final stages of alluviation. Archaeological testing is imperative. A dressed, undecorated stele (No. 47) is buried within the lower half of this structure or barrier (see also Krencker 1913:Plate 1). Nearby, lobes of soil wash and rubble encroach on the Mai Hejjá from the west, locally covering stelae. These deposits form lateral extensions of alluvial fans coming down from Beta Giyorgis and interdigitate with the cobble-grade facies of the Mai Hejjá.

The Mai Shum Reservoir. Mai Shum is an artificial rainwater cistern, recently enlarged. In 1906 this reservoir was semicircular, 65 m in diameter and up to 5 m deep; waters coming down the hillsides of the Mai Qoho were held back by a broad, arcuate retaining wall of dry mortar rising almost vertically 4 m on the inside (see Lüpke in Krencker 1913:70 ff., Plate 1). At that time it formed the sole, proximal water source for Axum and was almost empty in the middle of the dry season (January 13–April 6, 1906). However, the older literature frequently refers to more abundant waters (Table 1). Given a small, high catchment, dominated by two phonolitic plugs, a deep-seated aquifer is excluded. It is difficult to evaluate the role of seasonality in the changing abundance of the cistern's water supplies, but Table 1 argues for deterioration of surface runoff, shallow aquifers, seepage, and stream base flow since the mid-nineteenth century.

The cistern itself was constructed or restored A.D. 1426, according to local tradition as well as the Egyptian historian Makrizi (Monneret de Villard 1938:8–11). Nonetheless, the broad weathered, rock-cut steps leading down to water level from the adjacent cliff indicate an earlier, Axumite origin. The structure is identical to a South Arabian *karif*, used to collect and store runoff for irrigation (see Serjeant 1964).

Archaeo-Sedimentology of Stele Park. The soil and sediment record of the upper Mai Hejjá is complemented within Axum by two key study areas, the "obelisk" field of Stele Park, and the church compound of Mary of Zion, in the Debterá quarter.

The complex stratigraphy of the related foundations and retaining walls under Stele Park are below a + 8.5-m surface of the Mai Hejjá (Figure 3d), formed by interfingering artificial fills and footslope colluvium, grading up to the base of Beta Giyorgis. This stratigraphy is synthesized in Figure 4, on the basis of (a) successive excavation reports (Leclant 1959; Chittick 1974, personal communication 1974–1975), (b) analysis of 24 sediment samples provided by H. N. Chittick (15 from his trench XII FW), and (c) direct study of all exposed sections, particularly the 3.5-m sequence above the "Tomb of the False Door" (see Chittick 1974), removed during Chittick's 1974 season.

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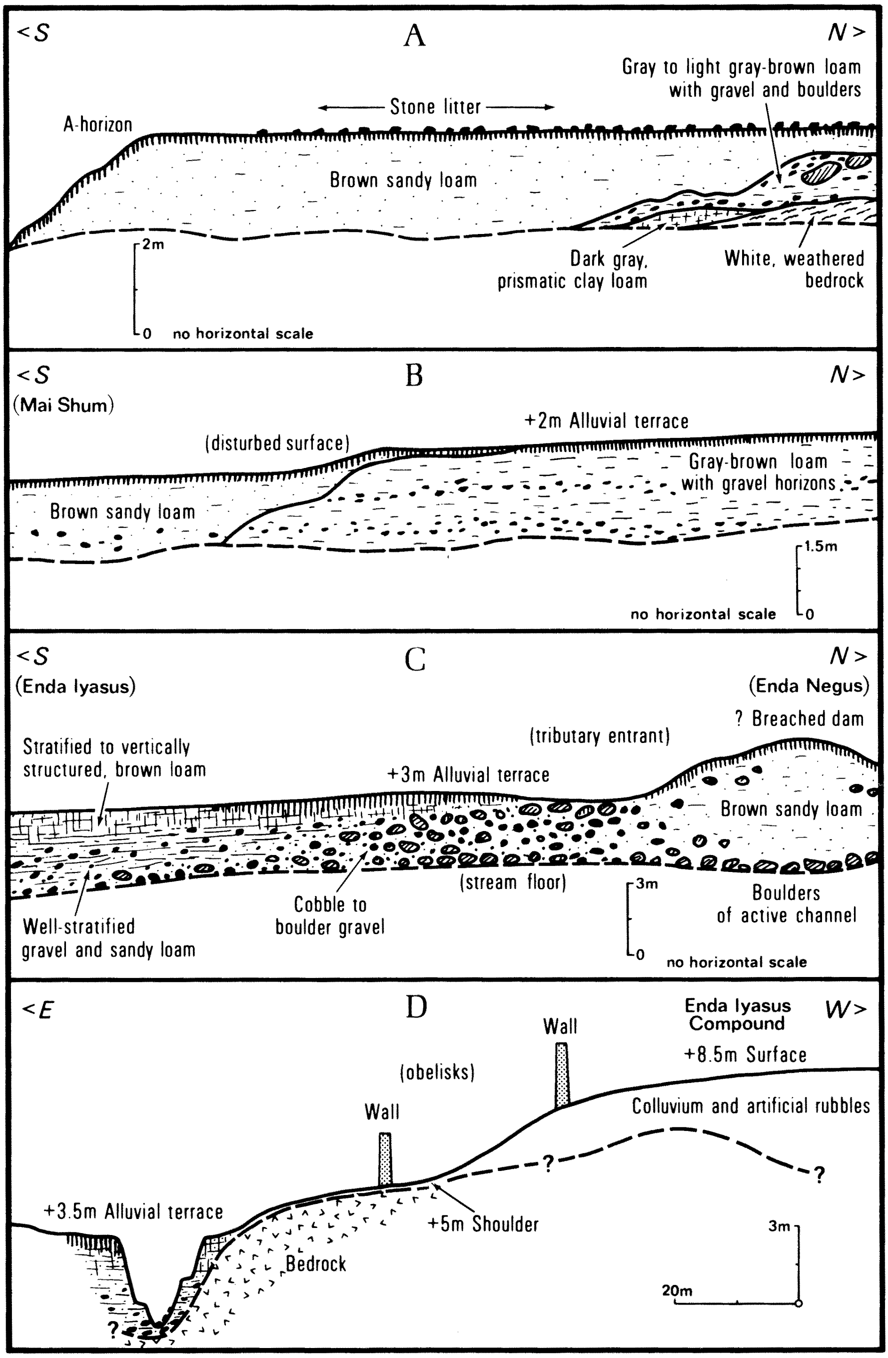

Figure 3. Schematic alluvial sections of upper Mai Hejjá drainage: (a) 550 m north of Mai Shum cistern (Figure 2:1); (b) 50 m north of Mai Shum (Figure 2:2); (c) between Enda Negus and Enda Iyasus; and (d) at Enda Iyasus. The longitudinal sections A, B, and C have no horizontal scale.

At the base is a low dome of heavily weathered syenite, altered to a mottled, yellowish brown (10 YR), friable "sandstone," in which former zeolites are filled by a very dark brown (10 YR) clay. The geo-archaeological units are detailed in Table 2. This sequence records most of the key social and environmental changes of the last two millennia.

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Table 1. Early Reports on Water Availability in Axum.

1861	Mai Shum cistern fed by a brook in November (Heuglin 1868:151), but Axum lacks water from January until July, despite the cistern (Steudner 1862).
1814	Abundant "good well-water" in Axum and many wells, although very few were clean and operational (Pearce 1831:162).
1770	In mid-January Axum "watered by a small stream, which flows all the year from a fountain in the narrow valley, where stand the rows of obelisks. The spring is received into a magnificent basin of 150 feet square, and hence it is carried, at pleasure, to water the neighbouring gardens . . . " (Bruce 1790, III:460–461).
1660s	Axum had a fountain that periodically "flows over and gives a very plentiful stream of clear water" (G. Baratti in Monneret de Villard 1938:78).
1520	Alvares noted "very good wells of water" and seems to mean the Mai Shum in discussing spring water (Beckingham and Huntingford 1961:155, 393, 512).
Early 1500s	"The rivers all rise in springs beside mountains, and they swell in rain" (Brother Thomas of Angot in Crawford 1958:171).
15th Century	"72 springs" in Axum (*Liber Axumae* in Beckingham and Huntingford 1961:522).

The original surface was deeply rotted bedrock, mantled with an unknown thickness of soil (unit 1).

The B-horizon, probably a noncalcareous brown clay loam, was stripped off to form part of a complex of artificial terraces during Early Axumite times (A.D. 100–350). Variable concentrations of local rock rubble, much of it partly decomposed, were first mixed into the artificial fills (unit 2) and a number of short, rough-hewn stelae then set on top of these low, 1.5-m terraces. Eventually, a level, built-up surface, as much as 2 m thick, had been created in the western part of Stele Park. Tall, plain but dressed stelae, associated with base plates hollowed out for offerings, were set on this surface. Later still, large masses of rocky fill, derived from fresh, angular quarry

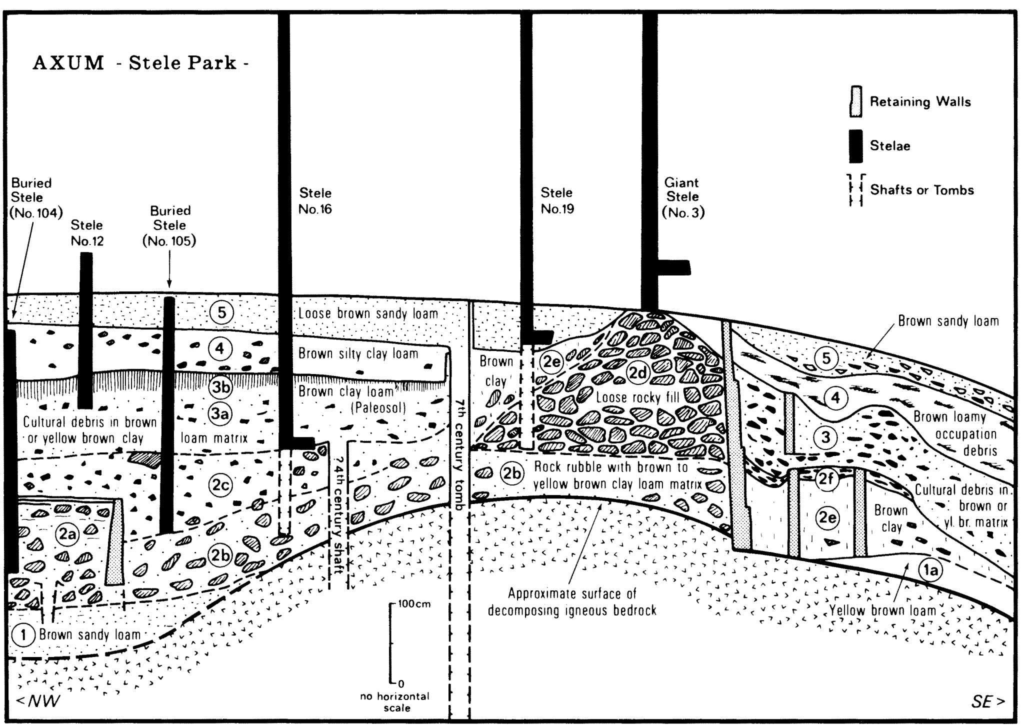

Figure 4. Composite and simplified cross-section of archaeological sediments below Stele Park. Based in part on Leclant (1959), Contenson (1959a), and Chittick (1974). No horizontal scale and strong vertical exaggeration.

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Table 2. Archaeo-Sedimentology of Stele Park, Axum.*

(5) *10-50 cm.* Loose, brown (10 YR), humic sandy loam, related to grading since about 1956.
(4) *50-75 cm.* Brown (10 YR), humic, silty clay loams with dispersed rubble, thickening to 150 cm on eastern slope, where hearths and burials are common (Contenson 1959a). Polished black or gray pottery, or dark coarse ware; 1890s coins and seventeenth century glass beads indicate recent settlement, photographed in 1906 (Krencker 1913:Plates 5, 8). Above False Door Tomb, 150 cm of similar wash, begin with lenticular back-dirt from robbers' pits and shafts. One meter of soil and rubble has been eroded or removed from the stelae platform and the seventh century shaft tomb (H. N. Chittick, revised dating personal communication 1980) during this time.
(3a, 3b) *100 cm.* West section: 1 m of deposit grades up from brown (10 YR) gritty loam, to yellowish brown (7.5-10 YR) clay loam, with dispersed, rotting rubble, to prismatic, brown (7.5 YR) clay loam. This profile is noncalcareous, compared with 3.5% $CaCo_3$ in underlying unit 2c; organic matter is less than 0.4%, compared with 3% in overlying unit 4. Unit 3b marks B-horizon of a partly intact paleosol. Fine red pottery is common, some sherds decorated with crosses; coins of late third to early eighth century kings (Chittick 1974). East section: sequence goes up from a lense of light gray, ashy loam; 15 to 85 cm of brown loam; 10 to 18 cm of interbedded, yellowish brown loamy lenses; and 35 cm of brown loam (Contenson 1959a). Abundant crude rubble, interspersed with occupation residues; conspicuous and irregular cultural stratification. Fine red pottery, coins, gold, and art objects suggest period of considerable prosperity, during which this section of Stele Park was built up with houses (Contenson 1959a). Rectangular walls built early in unit 3 rest on deposits that include coins of ca. A.D. 400 (King Wazebas). One of the last plain stelae (No. 12) implanted in surface of the buried soil 3b. At this time the largest stele (No. 1) collapsed while several others (Nos. 2, 4, 5, 6, and 31), some decorated, toppled over and were partly buried in unit 3 (Krencker 1913:Figures 22, 24, 32-33, 42, 75, Plate I).
(2d, 2e, 2f) *100-130 cm.* After piling up of 175 cm loose rocky fill (2c) behind a large retaining wall, a prismatic, brown (5-7.5 YR) clay with dispersed rubble accumulated on the slopes, between several parallel walls, as well as on top of the False Door Tomb. This clay contains polished red, black, bichrome red-and-black, and micaceous pottery of Early Axumite age (Contenson 1959a). Giant decorated stelae, with simulated temple fronts, now built on platforms such as 2d, linked to A.D. 355 date (1610 ± 40 years, P-2312, from XXII H, Chittick 1976). In front of the monuments, 20-30 cm quasi-sterile scree of yellowish brown clay loam (2f) rests on the eroded surface of 2e (Contenson 1959a), suggesting a phase of abandonment, destruction, or deliberate grading.
(2c) *60-100 cm.* Banded brown and yellowish brown (7.5-10 YR) clay loam, with secondary carbonates and dispersed, fine rotting rubble; grit and sand from fine orange potsherds, laminae of "fired" clay (marking hearths), and repeated terrace construction. The platform for stele No. 16, similar to unit 2a, was level with the top of unit 2c. C-14 dates of 25 B.C. and A.D. 130 (1960 ± 40 years, P-2310 from XXLLA, and 1820 ± 50, P-2311 from XXIIH, Chittick 1976) relate to incidental occupation on surface, but equivalent deposits above False Door Tomb include conical glass lamps attributed to third or fourth century (H. N. Chittick, personal communication 1975).
(2a, 2b) *100-140 cm.* Light yellowish brown (10 YR) loam, as matrix to decomposing rock rubble, grading up into banded, brown or yellowish brown clay loam, with much rotting rock. Secondary carbonates, humus, and sand-sized particles of red and orange potsherds are present, but no occupation residues. Laterally, an artificial terrace (unit 2a; trench XII FW, see Chittick 1974:Plate VIIa) comprises fresh, packed rock fill, behind a retaining wall and surfaced by deformed layers of oxidized, yellowish red (5 YR 5/6), stoney clay loam and overlying light gray (10 YR 7/2.5), ashy gritty loam, averaging 35 cm thick in total. One of earliest, rough-hewn stele (No. 104) was implanted into this terrace (2a) but later completely buried in sediment.
(1) *60 cm.* Brown to pale brown (10 YR), poorly structured, sandy loam, representing an undisturbed bedrock residual, probably BC-horizon of a truncated soil profile. Unit 1a, a foliated, mottled, yellowish brown loam that predates local occupation, is a more clayey facies, preserving structure of metamorphosed syenite.

* Munsell soil color chart hues.

rock, were piled up behind walls over 3 m high. The largest decorated stelae were prominently mounted on top of these. Then, thick masses of brown vertisolic clay were trapped in front or behind these foundation structures, where they are mixed with dispersed rock rubble. This brown clay closely resembles contemporaneous floodplain deposits of the Mai Hejjá, but is unlike any high-lying local soils. Either floodplain soils were being quarried and brought up to Stele Park, or sporadic, exceptionally high floods were depositing the clay in local sediment traps up to 4 m above the functional floodplain. A general enrichment of unit 2 soils (see Figure 4), as well as these clays with 1% to 3% carbonates, favors a "natural" interpretation.

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The Early Axumite ceremonial and burial area, still lacking evidence of habitation residues, was then abandoned and either eroded by rainwash or deliberately disturbed. A second episode of intensive use and reuse (Middle to Late Axumite) probably began during the late fourth century and continued until the early eighth century. Few elaborate structures were built, but much of Stele Park was covered with houses, although some stelae were still erected in sectors used primarily for mortuary purposes, e.g., the multiple shaft tombs (Chittick 1974). In most instances these strata (unit 3) represent water-worked colluvia more than they do artificial fills, occupation levels, or collapse rubbles. By the late eighth century the site had been more or less abandoned. Rainwash activity climaxed at about this time, but eventually the surface stabilized, and the dark, prismatically structured soil began to form. Many centuries would be necessary to oxidize the organic matter of the Axumite strata and to develop such a prominent profile. There is, significantly, no evidence in this geo-archaeological framework for the legendary destruction of Axum by groups from central Ethiopia led by a queen Yudit (Sergew 1972:227), although Arabic and Coptic Egyptian sources refer to this incident (ca. 980 B.C.) (Trimingham 1965:52 ff.).

The site remained undisturbed until the seventeenth century, or more probably until the fifteenth century, when the local quarter (Malaké Axum) is first verified in local tradition (Monneret de Villard 1938:13, 50). The small shrunken village sketched by Salt (in Mountnorris 1809:Plate, p. 82) in 1805 also covered part of Stele Park, as did the much larger town mapped by Lüpke (in Littmann 1913:Plate 2) in 1906 (see Figure 2). Again, much of the archaeological sediment (unit 4), particularly to the back of Stele Park, represents an extensive rainwash accumulation, locally over 1.5 m thick. Many of the robbers' shafts that intrude the sequence predate unit 4 (Figure 4). All the pit and tomb fills examined were highly organic, and occasionally show flood laminations, further suggesting that a major episode of vandalism dates from the fifteenth century settlement.

Subsequent modifications (reflected in unit 5) include the French excavations of 1954–1957, removal of the local houses, and concomitant landscaping of Stele Park.

The Debterá Floodplain. The Christian ceremonial center was not in the Stele Park but down on the centrally located Mai Hejjá floodplain. Tradition is unanimous that the first church of Mary of Zion, the Ethiopian cathedral, was built in a miraculously drained lake by the earliest converts (late fourth century) (Monneret de Villard 1938:49, 54; Beckingham and Huntingford 1961:521). This building was destroyed by the Muslim invader Ahmed Gragn A.D. 1535 and rebuilt 1579–1655 (Monneret de Villard 1938:21–31; Beckingham and Huntingford 1961:150–154). Situated directly on the floodplain, the cathedral was atop a raised platform, built 5 m above ground level (Lüpke 1913:Plate 6).

Test excavations by Monneret de Villard (1938:7–8) and Puglisi (1941) in the Mary of Zion compound, known as the Debterá (or "deacons' quarter"), verified 4 to 6 m of clayey and gravelly alluvium under Middle Axumite strata. Similar beds are exposed along the banks of the middle Mai Hejjá, as summarized in Table 3 (Site 7, Figure 2). These beds match the lower clayey horizons of Figure 3a-c, but the sandy, sherd-rich, uppermost alluvial facies of the Mai Hejjá is absent in the Debterá. Following the exposures downstream, the gully deepens to 6 m, with 4.5 m of alluvium exposed at site 8 (Figure 2). Finally, near the Adwa-Gonder road (Site 9, Figure 2), the Mai Hejjá has become broad and shallow, with only 2 m of brown clayey alluvium exposed. The stream then diverges across a shallow alluvial fan, built out over dark cracking clays, prior to disappearing onto the clay plain beyond (Figure 2).

Table 3. Floodplain Deposits under the Mary of Zion Compound.

(5) *80–100 cm.* Well-stratified, partly laminated, grayish brown clay loam with 30-cm humic A-horizon.
(4) *5 cm.* Lense of subrounded, medium-grade gravel, marking abrupt contact.
(3) *10–30 cm.* Prismatic, brown clay.
(2) *5 cm.* Gravel lenticle, possibly thickening locally to 100 cm (Puglisi 1941:Figure 5).
(1) *180–220 cm.* Massive, homogeneous, brown clay loam, resting on eroded surface of decomposing bedrock.

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The bed of the Mai Hejjá is now oversteepened in the 5- to 6-m deep stretch along the Debterá, although Lüpke's 1906 map shows a divergent, dispersal stream in the same area. Old photographs (Krencker 1913:Plate 1; Lüpke 1913:Plate 2) confirm poorly defined channels in the Debterá, shallower than those near Enda Iyasus. In other words, the stream gradient has changed significantly since 1906 and the now relatively straight channel suggests artificial deepening to improve drainage.

With an originally shallow channel, the "marshy ground" south of the Debterá on Salt's map of 1805 (Mountnorris 1809:Plate, p. 82) is readily explained. Salt was in Axum during September, at the end of the rainy season, verifying that the lowest parts of the Debterá were still part of the active floodplain. Periodic flooding obviously was a major reason for placing Mary of Zion on a 5-m raised platform in the fourth century. This basically confirms local tradition.

The archaeological materials on top of the Debterá floodplain have been tested along the northern perimeter of the cathedral compound (Table 4). This section verifies pre-Christian occupation and, importantly, points to a lack of building activity from the eighth century until after 1535. Also, unit (a) is below the top of the floodplain and provides a terminal date for the youngest clayey valley fill (unit 3). The topmost sandy alluvium of the Mai Hejjá terminates just upstream of the Debterá, at the approximate level of unit (5); the morphology of that alluvium indicates a shallow alluvial fan, limited to the upper valley. Abundant fine and coarse red pottery embedded in the terminal brown loams at Enda Iyasus (Figure 3d) argues that this fan and the related upvalley alluvium is coeval with unit 3 of Stele Park (Table 2).

The Piedmont West of Axum. A fuller perspective on recent landscape evolution is provided by the piedmonts below Beta Giyorgis and the Mai Qoho, adjacent to the Gonder Highway. A fresh road cut near the gate of the seventh century Dungur Villa (see Anfray 1972a) exposes a basal unit of at least 60-cm brown (10 YR) clay, embedding torrential lenses of crude cultural rubble, including red potsherds. The upper unit comprises 30–65 cm of very dark gray (10 YR) clay, torrentially bedded and compact, with dispersed or concentrated pockets of crude, angular rubble of cultural origin, including abundant sherds. Both generations of colluvium postdate the villa, the second evidently younger than its collapse. The 5° surface rises to 12° at the foot of Beta Giyorgis but flattens out to 2° across the Yudit Stele Field, south of the highway.

A longer section of 3 m, summarized in Table 5, has been recorded 250 m east of the Dungur Villa. Coins no younger than the early seventh century (King Wazena) indicate an age comparable to the Dungur Villa for units 3 to 7. But units 1 and 2 are earlier and certainly pre-Christian.

Additional sections are provided by Chittick's excavations (1974, personal communication 1974 with photos, sections and samples) among the 100-odd, mainly rough-hewn stelae of the Yudit Field. Two tests reached decomposing, mottled yellow and white, foliated bedrock ("basal clay") at 120 to 160 cm. Of particular interest are remnants of an in situ vertisolic A-horizon of prismatic, gray brown (10 YR), silty clay, some 30 to 50 cm thick. Over this is a complex interdigitation of cultural debris, with variable matrices of brown (7.5–10 YR) loam or clay loam, some disposed in distinct waterlaid beds. Glass goblets and beakers of probable Egyptian origin are of third or early fourth century age; the surface is littered with fine red sherds but coins are almost

Table 4. Archaeological Strata of the Mary of Zion Compound (after Contenson [1959b], and Anfray [1972a]).

(c) *100–200 cm.* Ashy soil, with much rubble and intersected by flagstone-covered tombs and various foundations, many quite recent. Black, gray, or micaceous pottery, with geometric, incised decorations. An age similar to unit 4 of Stele Park is implied, although the initial rubble may reflect Gragn's destruction of Mary of Zion.

(b) *300 cm.* Brown soil among rubble and architectural remains from two periods: late fourth to late sixth, and seventh to eighth centuries. Abundant coins as well as imported and local pottery, the latter red and in part decorated.

(a) *50 cm.* Dark brown matrix with abundant rubble, charcoal, and cattle bones. Architectural remains with coins of pre-Christian kings, dating from the third and early fourth centuries; polished, red, black, and gray pottery. Resting directly on unit 3 of Table 3.

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Table 5. Archaeological Strata 250 m East of Dungur Villa (after Puglisi [1941]).

(7) *60 cm.* Collapse rubble with coarse ware.
(6) *40 cm.* Humic sandy loam with reddish pottery.
(5) *40 cm.* Sandy loam with collapse rubble; polished black ware.
(4) *30 cm.* Humic, house-occupation debris with mainly undecorated ware.
(3) *50 cm.* Collapse rubble with decorated and undecorated or polished, reddish brown pottery.
(2) *40 cm.* Humic soil mixed with bone, ash, refuse, and abundant pottery (as unit 3).
(1) *40 cm.* Alluvial sand and clay with yellowish potsherds—on top of undisturbed clay.

absent (Chittick 1974). The Yudit Stele Field primarily represents an Early Axumite mortuary site. Built on top of the original vertisol, the tomb structures and stelae are in a matrix of soil wash that, in part, predates the Dungur Villa sequence.

In sum, the piedmonts west of Axum are mantled by at least three generations of colluvium: two younger than the seventh-century Dungur Villa (the first postabandonment, the second post-collapse), and one dating between the early fourth and late sixth centuries. There also appears to be an even earlier deposit of the Mai Lahlaha (unit 1, Table 5). The first two colluvia are loamier than the undisturbed clay soil, but lack obvious debris from the distant mountain slopes; instead, the additional silt and sand probably come from decomposing bedrock debris. The matrix of the postcollapse colluvium is distinctive and similar to the original soil; since the interval prior to collapse must have been short, a different stimulus to erosion is implied. Abandonment of the western margins of Axum appears to date from the eighth century, but burnt beams in a "late" building destroyed by fire gave surprisingly early calibrated C-14 dates of A.D. 50 and 420 (P-2316, 2317, 1550 ± 50 and 1890 ± 50 years) (Chittick 1974, 1976), probably reflecting old or reused timbers.

East of Axum. A long section of soil sediments is well exposed back of the Touring Hotel compound. At the base are at least 135 cm of reddish brown (5 YR), stoney silt loams that alternate with clay loams and pockets or lenticles of crude rubble. Over a sharp wavy break are 90 cm of reddish yellow (7.5 YR), stoney silt loam with vertical structure, and a humic, capping A-horizon. The surface of this footslope deposit is inclined 2° to the road but 8° and more up to the Mai Qoho hillside.

Both generations of soil wash are derived from ferruginous slope or upland soils, developed on deeply weathered bedrock: hematitic microconcentrations are found throughout the section, and coarse sands as well as rock fragments show almost complete zeolitization of the aegirine minerals; similarly, all exposed bedrock is much decomposed, and the typical color is a pale yellow (2.5 Y 8/3.5). The slope rubble inclusions in the lower wash horizon suggest relatively rapid accumulation, probably with the aid of viscous mass movements, and derive from a fairly deep B-horizon. The upper wash horizon can be traced all along the Mai Qoho footslope, and suggest more gradual sedimentation, with a strong textural peak in the coarse silt to fine sand range; derivation from a yellowish horizon of bedrock decomposition (BC-horizon) is indicated.

The two generations of soil wash at the Touring Hotel can be rudimentarily dated, although no potsherds were found. A 3.5-m-long, dressed but undecorated stele has been uncovered lying horizontally under 60 cm of the upper sediment in the western part of the hotel gardens (Anfray 1965). Insofar as can now be determined, this stele was very near the contact of the upper and lower units; presumably it had once been set up on the intervening surface. The stele is part of a cemetery, including the so-called Tomb of Bazin, which is directly covered by the younger unit of soil wash. This cemetery complex is older than that at Enda Kaleb and may therefore be Early Axumite (Anfray 1972a). By implication, the lower soil wash predates the fourth century.

GEO-ARCHAEOLOGICAL SYNTHESIS

The site-specific and other local data outlined above are collated in Figure 5 to facilitate comparison and correlation.

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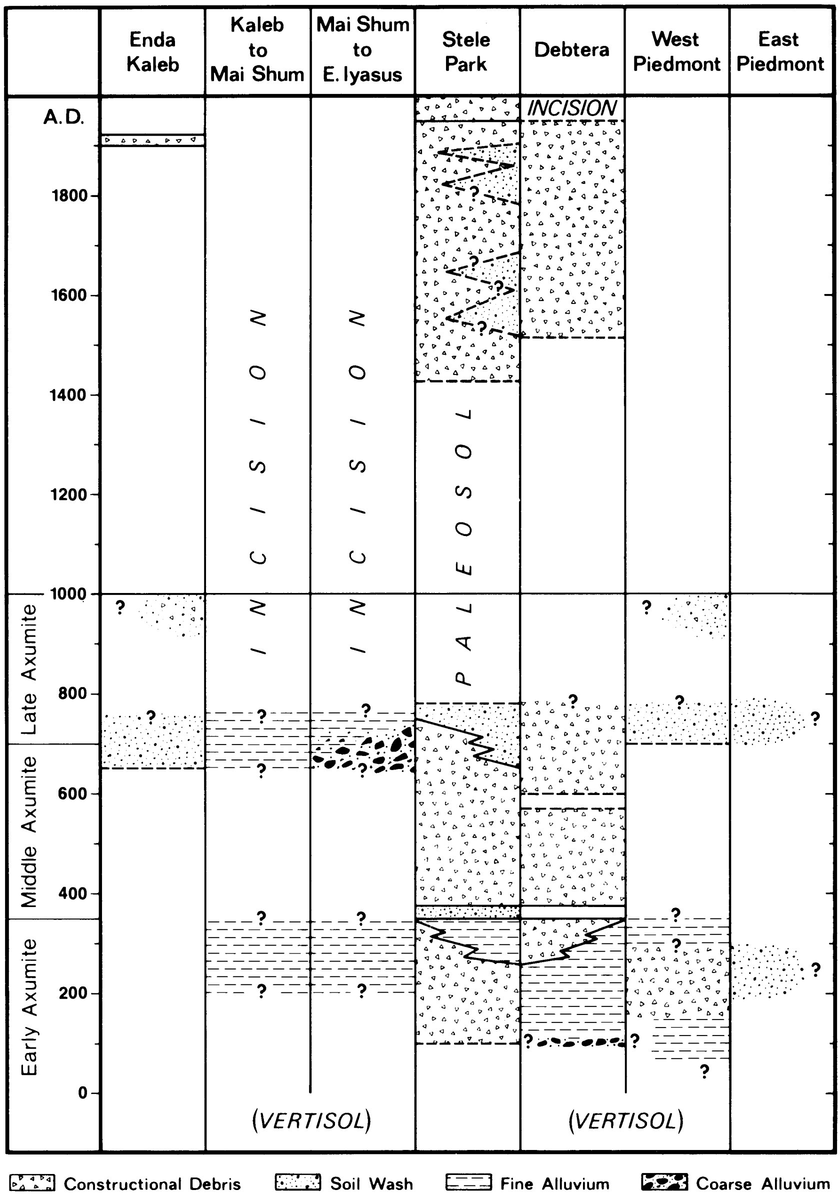

Figure 5. Geo-archaeological correlation chart for Axum.

Dating of the various soils, alluvia, soil wash units, and several types of constructional debris is a critical problem. Full and broken lines in the columns represent reasonably well-established temporal delimitations, but segments marked by interrogations are subjective in their placement. The chronometric framework essentially follows the obsidian hydration study of J. W. Michels (1975, personal communication 1977) in dating the Early Axumite phase from A.D. 100 to 350, the Middle from 350 to 700, and the Late from 700 to 1000.

The sediment facies identified in Figure 5 are simplified. In particular, "constructional debris" includes artificial terraces and their fills, architectural remains, collapse rubbles, and mixed and

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partially reworked cultural debris. The gradation to "soil wash" is a continuous one at Axum. The preeminently colluvial deposits singled out in Figure 5 include redeposited soils, water-laid soil mixed with cultural debris, and reworked collapse rubbles. The "alluvial" categories of Figure 5 represent fine and coarse-grade stream-laid deposits, including silts and clays once carried in suspension, sands and gravel carried by bed traction, and intermediate deposits of mixed grade, including sand-silt or sand-clay combinations with pockets, lenses, or isolated pebbles.

The oldest valley-floor surfaces around Axum are the basal, dark alluvial clays of the Mai Hejjá and the related vertisolic clays found over bedrock along the western piedmont. These cracking montmorillonitic clays delineate what were once seasonally wet surfaces. Their original formation, by both lateral accretion and pedogenesis, certainly predates Axumite settlement and may be related to the genesis of other Ethiopian vertisols in mid-Holocene times (see Semmel [1971], and Williams et al. [1977] for C-14 dating of such soils in the foothills of the Rift Escarpment at ca. 9410–4220 B. P., and in the central uplands at ca. 3865–3670 B.P.).

The first aggradation (I) coeval with Axumite settlement terminated A.D. 350 or so and began as early as A.D. 100. This episode includes the reworked, gray-brown vertisolic loams with dispersed gravel of the upper Mai Hejjá; the brown clays trapped in unit 2e of Stele Park; the prismatic brown clay (unit 3, and possibly 2) of the Debterá; the brown soil wash and rubble of the Yudit Stele Field, and possibly the sand and clay of the Mai Lahlaha; the basal, reddish slope loams at the Touring Hotel; and, finally, the reworked rubble on top of the pre-Christian strata at Stele Park (unit 2f).

The processual pattern suggested by this array of early Axumite deposits is one of strong periodic floods, wet slope soils, and seasonally abundant moisture. Deposition of a meter or two of relatively fine sediment across the Mai Hejjá floodplain and over much of the adjacent piedmonts implies a considerable mobilization of material through a large part of the watershed. To achieve this much within one to three centuries implies culturally accelerated soil erosion (see Butzer 1974), in response to partial devegetation, deterioration of ground cover, an increased ratio of immediate surface runoff after rains, and higher peak discharge. But the sediments themselves are not consonant with a simple "cultural" interpretation; those of the Mai Hejjá floodplain and the Touring Hotel would, in a Pleistocene context, be comfortably interpreted by a shift in slope equilibrium controls, related to heavier rains or greater seasonal periodicity of runoff. In the context of intensifying land use in Early Axum, I would argue for a coincidence of acultural and cultural inputs into the environmental system. The composite result was a rapid and dramatic change in the soil landscape that, in overall evaluation, did not significantly change potential soil productivity.

The second aggradation phase (II) began about A.D. 650 and probably lasted 150 years or so. Included here are the waterlaid soil and cultural debris of Enda Kaleb; the crude gravels and brown sandy loams of the upper Mai Hejjá; the reworked cultural debris of Stele Park; the stoney colluvial soil of the Dungur Villa; and the redeposited slope soil behind the Touring Hotel.

These Middle to Late Axumite deposits also have a modal thickness of a meter or two, but the sediment character differs from that of aggradation I. There is little trace of vertisolic derivatives, but much slope rubble and architectural debris. Some of this material was reworked by water in very local settings, but much of it implies vigorous denudation of the slopes above Axum, so for example the tongue of cobble and block rubble coming down the gully of Beta Giyorgis into the Mai Hejjá near Enda Negus. Interpretation seems unequivocal: soil and slope instability in response to overintensive land use, particularly of marginal surfaces, combined with widespread field and settlement abandonment. At the same time, the fluvial competence necessary to flush blocks across a footslope would be inconceivable without mudflows set in train by periodic, very heavy rains, although soil moisture and ground cover were significantly less than during aggradation I.

The net impact of aggradation II was negative: many slopes that had thin cambisols were now reduced to lithosols which allowed no more than marginal browsing or charcoaling activities; extensive agricultural surfaces on top of or at the foot of Beta Giyorgis and the Mai Qoho were either destroyed or reduced to a small fraction of their agricultural potential; even on the gentler

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lowland slopes, the more organic and better aerated A-horizons were selectively stripped, or mantled with sandy-stoney soil derivatives from BC- and C-horizons. The examples cited here represent no more than a selection of features that were part of an intensive regional phenomenon: culturally induced environmental degradation. The evidence in regard to soils is direct; the case for vegetation and agriculture is indirect, but no less convincing.

The third phase of aggradation (III) is not proven beyond reasonable doubt, and dating remains elusive. But the postcollapse soil wash at both Enda Kaleb and the Dungur Villa is distinctive and must be Late Axumite. To what extent these deposits represent a minor postscript to aggradation II, or an important episode of renewed soil erosion, cannot be established without more and better dated contexts. It is also possible that phase III marks nothing other than a short-term geomorphic readjustment, following a late episode of abandonment or destruction.

The last phase of aggradation (IV) would include the soil wash and debris in Stele Park, reworked collapse-rubbles in the Debterá, and various twentieth-century disturbances. Their general validity and specific interpretation are unclear, based solely on local evidence. Considered in the context of recent soil erosion in the Semien (Hürni 1975) and around Makallé (Virgo and Munro 1978), they do point to renewed land use pressures on an already denuded landscape during the last century or so. Near Axum this pressure was exacerbated by the long-term residence of the emperor Yohannes on top of the Mai Qoho with his great standing army and many hundreds of hangers-on during the 1880s (Lüpke 1913:42ff.; Pankhurst 1968:546 ff., 554, 569ff.). Then, from 1888–1892, northern Ethiopia was devastated by a great drought and locust plague (Pankhurst 1966) that far exceeded the impact of the drought of 1971–1974.

ENVIRONMENTAL PROCESSES AND HISTORICAL INTERPRETATION

This geo-archaeological study of Axum demonstrates a suite of landscape changes physically linked with changing settlement patterns. Both phenomena form components of the same human ecosystem, and there must be significant spheres of interaction. More comprehensive analysis of possible nodes of intersection must await publication of Michels's 1974 archaeological survey of the Shiré Plateau (see Michels 1979), as well as further geo-archaeological work at other sites. But several basic configurations are clear and warrant broader interpretative discussion.

There is no evidence for settlement at or around Axum until about A.D. 100 (see Anfray 1972a; Chittick 1974), when Stele Park began to emerge as a regional ceremonial center, and small population nuclei were established in the Yudit Stele Field (Chittick 1974), on top of Beta Giyorgis (Godet 1977), and in the upper Mai Hejjá valley (J. W. Michels, personal communication 1977). During the mid-fourth century, settlement patterns shifted radically, with a large town growing around Stele Park and within the present city limits. The primacy of Axum over an array of much older towns in northern Ethiopia was unchallenged. By A.D. 500 Axum was more extensive (about 75 ha) and possibly as densely settled as its modern counterpart (53 ha with about 20,000 inhabitants). The town of 1906 (see maps and photography in Krencker [1913] and Lüpke [1913]) covered 45 ha scattered with over 650 houses, some 100 in church compounds and probably belonging to clergy. This supports G. Rohlfs's 1881 estimate (Monneret de Villard 1938:120) of 5,000 inhabitants with 800 priests, prior to demographic decline during the famine years 1888–1892. It also argues for between 10,000 and 20,000 people in the Middle Axumite city. Royal palaces and elite villas were concentrated along the western margins of the city, with a major cemetery at Enda Kaleb (see Anfray 1972a). The splendor of the multistoried buildings was noted by Cosmas ca. A.D. 525 (Wolska-Conus 1968), but the basic residential houses were probably little different from the thatched, round huts of wood, wattle, and mud of the nineteenth century (see Lüpke 1913).

During the late sixth century the Axumite kingdom became notably passive in its foreign policy, and a century later gold coins were no longer struck (Anfray 1968), implying a loss of commercial access to or military control over the fringes of the Abyssinian Plateau. Between A.D. 702 and 715, the Arabs eliminated the Axumite fleet and destroyed Adulis (Anfray 1974; Kobishchanov 1979:116ff.). Cut off from its trade goods and limited to only sporadic and increasingly indirect ac-

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cess to its markets, Axumite power collapsed. No more coins were minted. Within a few generations the capital had been reduced to a loose cluster of villages, and elite residences were set up in secluded defensive locations on steep mountainsides behind Enda Kaleb (J. W. Michels, personal communication 1977). A similar decline is apparent in Matara and other key cities (Anfray 1972b); furthermore, the earliest rock-cut churches hidden along the rugged margins of the Abyssinian Plateau date from about this time (Gerster 1972).

Axum was on the defensive, at first against Beja pastoralists of the Baraka lowlands who conquered the plateau of Asmara in the eighth century (Conti-Rossini 1928:268; Trimingham 1965: 49–51). Control of the incense forests along the plateau margins was certainly lost at this time, as was the ability to divert the lowland pastoralists' cattle to trade against gold, ivory and civet. According to Ethiopian tradition, the Axumite king took up a new residence some 360 km further south, near Lake Haik, ca. A.D. 870 (Doresse 1957, II:5, 29; Tamrat 1972:35–36). This may explain why Arab sources which, in A.D. 872, ca. 900, and 935 refer to the Christian kingdom in the hinterland of Adulis, no longer mention Axum (Trimingham 1965:51; Kobishchanov 1979:119). After the king had abandoned Axum, the Wolkait of the Tekeze Valley sacked what was left of the town, provoking retaliation by the prince of Axum, Dan'el (Conti-Rossini 1928:303–305; Doresse 1957, II:6–7; Kobishchanov 1979:120). Probably before the conquest of "Yudit" ca. A.D. 980, even the metropolitans of the Ethiopian Church forsook Axum, in favor of Nazret, in the distant mountains of the Great Escarpment (Anfray 1970). Later, a cultural renaissance began when, during the mid-eleventh century (Sergew 1972:242), the trappings of royalty passed to a usurping non-Axumite family, the Zagwé, who held a seat of power in the mountain fastness of Lasta, in the humid, central part of the plateau some 240 km south of Axum (Figure 1).

The precipitous decline of Axum as a world power, as a prosperous civilization, and as a populous city began at least a century before the Arabs first cut its commercial lifeline. It is probable that the destructive wars between Byzantium and Persia, A.D. 540–561 and especially A.D. 602–632, began to dry up the market for luxury goods in the increasingly impoverished Roman Empire, while Persian fleets endangered the route to India and controlled South Arabia during the early seventh century. Limited to its own modest resource base of stockraising and small-scale agriculture, Axum apparently could not support its political and socio-economic superstructure.

The geo-archaeological record illuminates a central variable of the Axumite ecosystem. The local evidence for aggradation I supports a period of unusually abundant water ca. A.D. 100–350, culminating in widespread soil dislocation but with little net change in potential productivity. Mobilization of slope soils was probably accelerated by intensifying land use, but a primary climatic stimulus is indicated. The case for a moister and possibly cooler climate from the first to the fourth century is strong, and the agricultural implications are momentous. Two crops per year, in combination with ample water for irrigation, would greatly enhance productivity. Whether this beneficial, long-term climatic shift persisted after A.D. 350 until the time of aggradation II is impossible to tell from the local evidence.

Whereas aggradation I suggests a geomorphic response to increasing available moisture, accelerated by human interference, aggradation II represents the impact of land use, intensified by heavier rains leading to rapid, torrential runoff. The range of late seventh- and eighth-century features at Axum resembles "post-classical" alluvia and colluvia of the Mediterranean Basin (Vita-Finzi 1969). "Post-classical" refers to deposits dating just after periods of intensive land use and economic prosperity, but varying in age from 1500 B.C. to A.D. 1000 (see Butzer 1974, 1980a). Characteristic elements of such deposits are the facies (reworked slope soils and cultural debris) and the association with phases of depopulation and partial land abandonment. So it is at Axum, too.

Axumite croplands were concentrated on hilltops and sloping piedmonts, locations susceptible to erosion, particularly when not maintained during the time of eighth-century depopulation. Modern observations on cambisols around Makallé indicate that rain and livestock trampling on unplowed fields forms a surface crust that limits water infiltration and so favors rapid and destructive runoff during storms (R. N. Munro, personal communication 1979; Hunting Technical

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Services 1976:annex 1). This implies that abandoned lands would be particularly susceptible to soil erosion, especially during the season of maximum rainfall intensity, i.e., July and August. Bruce (1790:III, 125) also noted the grazing of goats on local hillslopes, and it can be inferred that pastoral or fuel-gathering pressures on fragile hillside ecosystems would intensify during times of agricultural decline. By implication, the woodlands that had once harbored great elephant herds were now in large part removed, requiring ivory trading far inside central Ethiopia.

Much of the debris mobilized in aggradation II was occupation rubble from abandoned living quarters and deteriorating monumental architecture. Present archaeological resolution shows no tangible horizons of deliberate destruction, even though Axum may have been repeatedly pillaged by the Beja and Wolkait, not to mention the razzia of the Yudit. Axumite foundations and construction techniques were not very stable, requiring repeated rebuilding (Anfray 1972a, 1972b). There is considerable deformation among the platforms under Stele Park (photographs courtesy of H. N. Chittick, personal communication 1975), resulting from differential autocompaction of artificial fills. Similarly, the conspicuous tilts of the smaller stelae on the 1906 photography (e.g., Krencker 1913:Plate 1) were due to unstable foundations. The fallen, decorated monoliths are aligned along the sharp edge of the 8-m surface between Enda Negus and Stele Park, and have fallen forward across the slope down to the 3-m Mai Hejjá floodplain; the physical evidence indicates slope instability, erosion, or undermining as responsible factors. Local tradition in the 1630s claimed that Turkish troops had knocked over six or seven stelae (Monneret de Villard 1938:63), but Bent (1896:190) observed: "I imagine that the washing away of the soil by the stream (the Mai Hejjá) has been the reason, causing them to lose their balance and fall forward." In fact, partial burial in late Axumite hillwash in most instances precludes seventeenth-century collapse. It is also pertinent that as much as 1.5 m of foundation material have been eroded from around the base of the giant standing stele (Chittick 1974). In sum, an abundant sediment supply from unprotected soils and derelict structures was a major component in aggradation II.

Archaeological dating of aggradation II *after* the major building phase of the sixth and seventh centuries militates against a thesis that land degradation triggered—rather than exacerbated—Axumite economic decline. Wood beams were still used extensively in elite constructions of the seventh century (Anfray 1972a; Chittick 1974), arguing for some suitable timber within reasonable distance. This does not, however, negate the probability of devegetation of most of Shiré, and particularly of the more precarious slopes, by the end of the Middle Axumite period. The block rubbles mobilized on the lower slopes of Beta Giyorgis not only point to unimpeded surface runoff but unusual discharge peaks. It is therefore probable that heavier rains, which had once favored Early and Middle Axumite agriculture, ultimately accelerated destruction of Axum's soils. The extent to which increasingly unreliable rainfall patterns during the eighth century further reduced available ground cover remains beyond resolution for the moment. In any event, this new climatic trend must have reduced the reliability of crop yields. The potential coagency of this eighth-century climatic shift in creating a crisis in Axumite agriculture, reducing carrying capacity and favoring demographic decline, must remain hypothetical until more data are available; hence, further exploration is essential.

Whatever the exact nature of the active or passive interactions between eighth-century Axum and its environment, the landscape was ultimately denuded and degraded. The shift of political power southward, to Lasta and even to central Ethiopia, during the ninth and tenth centuries (Tamrat 1972), may have been influenced more by considerations of environment than of security; although these regions were equally subject to raiding by unsubjugated border peoples, the vegetation cover here was still largely undisturbed, the soils deep and fertile, and high productivity was assured by an 8- or 9-month growing season.

Aggradation III, dating somewhere between the mid-eighth and late tenth centuries, represents collapse rubble and related soil wash. The impetus may have been destructive pastoralist raids, but the point would be too difficult to prove. In any event, aggradation was not of landscape significance, with most surfaces stable from the eighth to the fifteenth centuries. Axum had been almost totally abandoned, and it is probable that the vegetation cover and soil mantle of its en-

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virons during the ninth and tenth centuries were as sparse as they were when photographed by the German expedition in 1906 (Littman 1913:Plate 1; Krencker 1913:Plate 1).

During the fifteenth century, renovation of Mary of Zion (1404), reconstruction of the Mai Shum (in 1426), not to mention Ethiopian tradition referring to several residential quarters of Axum and its 11 churches (*Liber Axumae*, see Monneret de Villard 1938:13, 21, 49–54), all point to demographic revival and a large town. Sources of 1520 and 1522 also document a new agricultural prosperity (Beckingham and Huntingford 1961:161; Crawford 1958:141, 143). But in 1535 Axum was plundered by Gragn, and Mary of Zion put to the torch. Although the thick walls of the 27 by 54 m church still stood in 1624–1633, the new, smaller church (15 by 38 m) had been begun in 1579 within them (Beckingham and Huntingford 1954:90, 1961:150–153; Monneret de Villard 1938:22–30). Following the famine of 1540–1543 and the Galla raid of 1611, Axum had shrunk to some 150 or 200 houses, perhaps 1,000 inhabitants, by 1620 when Paes described the now miserable settlement (Monneret de Villard 1938:67). Further catastrophies followed: the locust plague of 1625–1627 destroyed all crops and cattle, leading to famine, pestilence, mass deaths, and even cannibalism (Pankhurst 1972); the locust infestation of 1633–1635 coincided with a great cholera epidemic (Pankhurst 1961:234, 1972), followed in 1693 by a major smallpox outbreak, and in 1747–1749 by further locust plagues (Pankhurst 1961:236, 239, 1972). Subsequent population estimates for Axum include some 4,000 people (600 houses) in 1770, 1,500 people (350 houses) in 1838, no more than 2,000–3,000 in 1861, and 5,000 in 1881 (Monneret de Villard 1938:14, 82, 105, 120), shortly before the calamitous drought, rinderpest and famine of 1888–1892 (Pankhurst 1966). Royal building activity, at Mary of Zion, is last recorded in 1655 and 1750 (Monneret de Villard 1938:23), lending credence to a higher population in 1770 than during the subsequent era of political anarchy and strife of 1780–1855.

Since aggradation IV was restricted to areas of active settlement, it can be tentatively interpreted within this demographic framework of sudden or protracted depopulation 1535–1543, 1611–1634, 1780–1855, and 1888–1892. Figure 5 suggests several phases of localized erosion, each following episodes of urban depopulation. This is no more than a tentative working hypothesis. It is relevant that a great deal of artificial and natural disturbance has affected the town since 1500 or so, and the partial ecological revival of the Axumite environment was finally terminated during the 1880s. Only more extensive and exacting study can hope to clarify the details and the nature of possible relationships between geomorphology and population cycles since about 1400.

CONCLUSIONS

In final overview, this geo-archaeological examination of Axum supports the view that environmental resources cannot be treated as static variables in the ecosystems that represent ancient civilizations (Butzer 1976, 1979b). Axum provides a good example of how spatial and temporal availability of resources, and the interactions between a society and its resource base, can be of fundamental significance in the analysis of historical process.

Axum owed its power to its partial control of an international exchange network inaugurated by pharaonic Egypt three millennia earlier. Its market resources, including gold, ivory, incense, civet, cattle, and animal products, were found in several different environments occupied by alien peoples who had varying relationships to Axum. Tribute from the lowland pastoralists probably also guaranteed a supply of cattle adequate to support a growing home population. But the local subsistence base was substantially augmented by a climatic shift during the first century A.D. that reinforced the spring rains, extended the rainy season from 3 1/2 to 6 or 7 months, vastly improved the surface and subsurface water supply, doubled the length of the growing season, and created an environment comparable to that of modern central Ethiopia—where two crops can be grown per annum without the aid of irrigation. This appears to explain how one of the marginal agricultural environments of Ethiopia was able to support the demographic base that made this farflung commercial empire possible. It may also explain why no Axumite rural settlement expan-

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sion into the moister, more fertile, and naturally productive lands of Begemder or Lasta can be verified during the heyday of Axumite power.

After 602 Axum's export markets and control of the seas were threatened and, beginning in 715, Axum became increasingly landlocked and isolated. Gold, like cattle, came from the semiarid lowlands which Axum temporarily dominated but never fully controlled. Ivory was initially abundant in local upland forests but, as both trees and elephants became scarce, ivory like civet had to be obtained increasingly from distant parts of humid Ethiopia. As international profits from the exchange network declined, Axum lost its ability to control its own raw material sources and that network collapsed. The already persistent environmental pressure of a large population to maintain a high level of regional food production had to be intensified. The result was a wave of soil erosion that began on a local scale ca. A.D. 650 and attained catastrophic proportions after 700. Presumably complex socio-economic inputs compounded the problem. These are traditionally reflected in declining maintenance, deterioration and partial abandonment of marginal crop land, shifts to destructive pastoral exploitation, and eventual, wholesale and irreversible land degradation. This syndrome was possibly accelerated by an apparent decline in rainfall reliability beginning 730–760, with the presumed result that an abbreviated modern growing season was reestablished during the ninth century.

By 800, Axum had almost ceased to exist, and its demographic resources were barely adequate to stop the once tributary pastoralists of the border marches from pillaging the defenseless countryside. The elite and a share of the common people now chose to abandon the denuded Axumite landscape in favor of settlement on the virgin soils of central Ethiopia. It was there, in Lasta and Begemder, that the foundations were laid for the thirteenth-century emergence of the modern Ethiopian state. Axum has become a peripheral backwater, important only as a symbol of royal and religious authority, until the revolutionary break with Ethiopia's past in September 1974.

The rise and fall of Axum can both be linked to the interplay of the same variables: foreign trade, access to resources, productivity, demography, and sociopolitical structures. The interactions between these variables were fundamentally different during the growth and florescence of Axum than during its decay. The breakdown of Axumite civilization was the result of a chance concatenation of mutually reinforcing processes that led to environmental degradation and precipitous demographic decline. Axum did not revive and the new cycle of Ethiopian empire evident by the thirteenth century was predicated on a new constellation of key variables and was centered in a different environment.

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