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RECENT GEOMORPHIC HISTORY IN THE AREA OF EXPERIMENTAL WATERSHEDS 1, 2, 3, 9, AND 10, H. J. ANDREWS FOREST

F. J. Swanson and M. E. James
Geology Department, University of Oregon

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ABSTRACT

Studies in the lower Lookout Creek-Blue River area have revealed a geomorphic history including glaciation and the development of three alluvial surfaces, presently active alluvial cones and older, deeply dissected cone remnants. Results are based on landform mapping, analysis of the types and distributions of surficial sediments, and the distribution of Mazama ash. Presence of the ash makes it possible to date geomorphic features relative to a time horizon about 8,000 years in age. This work has served to identify individual cones which will be studied further to learn the erosional histories of specific watersheds.

BEDROCK GEOLOGY

Within the area mapped in Figure 1, the bedrock geology exposed in creek banks and road cuts includes a series of altered volcanoclastic sediments of the middle Oligocene to early Miocene Little Butte Formation (Peck et al. 1964). This country rock has been intruded by numerous, northwest trending dikes which range in composition from basalt to rhyolite. The clastic rocks vary in grain size from mudstones to very coarse, poorly sorted breccias deposited by air fall, ash flow, fluvial, lacustrine, and massive mudflow processes.

The ratio of volume of dike to clastic material was measured in two road cut traverses and were found to be 1:3.5 and 1:10. These figures were determined in areas of abundant dikes and the ratio of dike:clastic material for the area of Figure 1 as a whole is probably closer to 1:15. Although less altered and deeply weathered than the clastic rocks, dikes have a very subdued influence on the gross morphology of hill slopes and drainage patterns.

MAZAMA ASH

Beds of yellow, pumiceous volcanic ash occur within and on top of numerous alluvial and colluvial deposits and, therefore, serve as a useful time horizon in the geomorphic development of the Blue River area. Occurrence of the ash and its megascopic and microscopic appearance are similar from one site to the next, indicating that all of the deposits were probably derived from ashfall material from a single source. The mineralogy of associated crystals (62-500μ fraction) in five ash samples collected from alluvial and colluvial deposits fall within the ranges of values characteristic of Mazama ash reported by Kittleman (1973). Crystal size and shape distributions and other features such as distinctive glass and bubble-filled inclusions in plagioclase phenocrysts are also identical in Blue River samples and slides of known Mazama air fall ash. These observations clearly distinguish the Blue

River ash from tephra erupted from other nearby vents (including Devils Hill near South Sister and Newberry Caldera) and strongly argue that it was derived from the climactic eruption of Mount Mazama about 7000 ^{14}C years before present (Kittleman, 1973). Suess, Stuiver, and others (e.g., Olsson, 1970) have shown that this date is approximately equal to 8,000 calendar years ago.

GEOMORPHIC HISTORY

The earliest Quaternary sediments in the mapped area are a series of tills and related glaciofluvial and glaciolacustrine deposits. This material may be seen overlying a glacially striated surface in several exposures unearthed during construction of the Blue River Reservoir. Although much of the valley bottoms of Blue River and Lookout Creek must have been glaciated in the past, only a few patches of glacial pavement can be observed today because the volcanoclastic bedrock weathers vary rapidly when exposed to the atmosphere. However, the semi-consolidated glacial clastics, notably the silt and fine sand lacustrine deposits, are exposed at many points in the creek banks along Blue River below Tidbits Creek and in several scattered outcrops along Lookout Creek (Figure 2).

This glaciation profoundly changed the lower Blue River drainage pattern. Exploratory drilling and trenching in the reservoir area by the Army Corps of Engineers have shown that there is a wedge of glacial sediments filling an ancient Blue River valley from about Tidbits Creek downstream seven kilometers to a point beyond the saddle dam. A profile drilled across the saddle dam area (shown in Figure 2) revealed more than 60 meters of sediment filling the old Blue River channel which apparently once drained directly into the McKenzie River in the NW¼ Sec. 24 T16S R4E. This great thickness of fill suggests that the westward turn of Blue River in the vicinity of Scout Creek may have resulted from ice damming by glaciers in the main McKenzie valley. Near the mouth of Scout Creek Blue River flows over a bedrock surface which acts as a base level for the river segment upstream to Lookout Creek. Over this course the river now cuts into the relatively soft glacial sediments.

Several lines of evidence indicate that glaciation of lower Blue River and the shift in drainage pattern occurred in pre-latest Wisconsin time. Sediments in the saddle dam area are much more deeply weathered than latest Wisconsin glacial material near the confluence of Lost Creek and McKenzie River. In addition, Roger Parsons and Randy Brown have obtained two pertinent ^{14}C dates. A sample of wood from glaciofluvial sediments in the reservoir area approximately 0.6 km downstream from watershed 9 is dated at greater than 40,000 years old. The second sample, collected from a bouldery diamicton immediately underlying the lacustrine sediments is greater than 35,500 years old These dates are minimum estimates of the time of glaciation of the main McKenzie valley in the vicinity of the saddle dam. The lake beds occur at elevations up to 25 meters above the top of the natural saddle dam, suggesting that they were deposited in a lake backed up at least in part by an ice dam.

The oldest alluvial geomorphic surface in the mapped area is a high cone and terrace complex above the mouth of watershed 3 and further upstream. The origin of this landform unit will be discussed in a later paper.

Subsequent fluvial action cut a terrace surface onto the glacial sediments and Tertiary bedrock. The associated terrace deposits are composed of two to four meters of well-rounded, well-imbricated cobbles and boulders with minor sandy interbeds which generally grade upward into less than a meter of unstratified silt to coarse sand overbank deposits. These relationships may be seen in an exposure along Blue River near the foot of watershed 9. Here the Mazama ash layer overlies, or may be interbedded with, the uppermost overbank sediments of Blue River and these units are buried beneath 1.5 meters of sub-angular to sub-rounded, poorly-sorted gravels from the adjacent tributary watershed. We can, therefore, infer that mainstream deposition on this terrace surface was completed about 8,000 years b.p. and that by that time Blue River and Lookout Creek had incised a deeper channel into bedrock and the glacial sediments. Temporal relationships among these and other geomorphic surfaces are shown schematically in Figure 3.

A minimum age of 8,000 years for the fluvial terrace suggests that it may be correlative with the Winkle geomorphic unit mapped by Balster and Parsons (1968) in the Willamette Valley. They determine a minimum age for the Winkle surface by the occurrence of Mazama ash in the upper meter of alluvium and a ^{14}C date of 5250±270 years on a hearth site in a shallow soil on the surface. Although long range correlations of geomorphic surfaces is tenuous, it does seem reasonable that the Blue River fluvial terrace and the Winkle surface developed in response to a single, but not necessarily sychronous, regional response of fluvial regimes to climate and vegetation changes during and post-deglaciation.

The modern vegetated floodplains of Blue River and Lookout Creek form the next lower geomorphic surface. In most areas, particularly within Blue River Reservoir, this surface has been cut onto glacial sediments and, in fact, the presence of older Quaternary sediments appears to control the geographic distribution of this surface. The top of the surface is two to four meters above modern low water level. Several Douglas-fir trees more than 400 years old have recently been cut from one segment of this surface, suggesting a minimum age of 400-500 years and indicating that the modern channel has been in its present position for at least that length of time. The floodplain has characteristics similar to the Ingram surface named by Balster and Parsons (1968).

The presently active channels of Blue River and Lookout Creek are mapped in Figure 1 as "modern channels." Along much of the channels above their confluence the streams are flowing on bedrock and active alluvium. For several kilometers downstream from that point, Blue River is cutting into the glacial sediments. The modern channel corresponds with the Horseshoe surface of Balster and Parsons (1968).

Alluvial cones have been constructed out onto the floodplain and fluvial terrace surface from the mouths of tributary streams. Surfaces of these fan-shaped wedges of sediment dip radially 5° to 10° from the apex of the cone. The cones have been constructed by perennial and intermittent alluvial processes (events of perhaps one per year recurrence interval) as well as by episodic debris torrents (recurring perhaps once every several centuries) which may have been partially reworked by the alluvial processes. Cross-sections of typical cones show sets of alluvial channel and fill structures and/or tabular beds resulting from sudden massive influxes of sediment in debris torrents. There may also be a general coarse to fine sediment grading from the head to the outer edge of the cone. Characteristics of individual cones, in terms of their size, morphology, internal stratigraphy, and extent of erosion by the tributary and mainstreams are functions of floodplain width and watershed variables such as area, channel length, average slope, and slope stability.

Within the mapped area it is possible to delineate several types of cones on the basis of their probable ages and their present stages of development. However, cone characteristics do fall on a continuum and, therefore, distinguishing cone types is somewhat subjective.

Cones labeled as "pre-Mazama ash" in Figure 1 were constructed at the mouths of larger watersheds (greater than approximately 40 ha) primarily by the accumulation of debris torrent material. This is most clearly seen in the case of watershed 3 where a road cut exposes a 15-meter section of the cone interior composed of a series of beds up to several meters in thickness. Individual sedimentation units are made up of sub-angular, unsorted material ranging from clay-size to blocks 1.5 meters long but with a notable absence of woody matter. Scattered patches of Mazama ash are found on the cone surface.

This internal stratigraphy indicates that these cones were constructed by periodic debris torrents during latest Wisconsin time and possibly up to 8,000 years ago. The paucity of wood in the old deposits contrasts strikingly with modern log-filled, debris torrent material (Fredriksen, 1963 and 1965). This difference may be in part related to an increase in amount of organic debris because of man's activities or it may have resulted from a natural bias in the sample--such as loss of organic matter by rotting. However, it may also reflect the presence of much sparser vegetation during the period of deposition--possibly scattered lodgepole pine forests (Heusser, 1960).

Cone morphology was greatly modified both during and after cone construction by mainstream overbank flow early in the development of the "fluvial terrace" surface and by dissection by both mainstream and tributary channels. Since the larger watersheds were being drained by perennial streams, channels were cut into the cone between debris torrent events. As the cone surface aggraded and downcutting by the tributary stream continued, the channel eventually became so deeply incised that cone construction ceased. This had occurred by about 8,000 years ago and subsequent debris torrents passed directly through the cone area and into the mainstream channel. The process of cone dissection was accelerated by downcutting of the mainstream channels which served to lower local base level. The upper sketch in Figure 4 shows a schematic radial section of this type of alluvial cone.

Cones built at the mouths of smaller watersheds are generally composed of better sorted, less angular and finer sediments than the "pre-Mazama ash" cones. An additional important distinction is that where the floodplain is broad enough to contain most of the cone, the surfaces of cones from small watersheds are still aggrading or are gullied to a depth of no more than two meters by the tributary stream (see Figure 4 for example of radial section).

Cones at the bases of very small watersheds (less than about 5 ha) usually absorb all runoff from the tributary stream and are therefore ungullied. In some cases their radial profiles tend to be lobate as a result of sudden loss of stream competence as the flow passes from a narrow bedrock channel out over the broad porous pile of alluvial material (see bottom of Figure 4 for example).

In numerous cones, beds of Mazama ash up to 25 cm in thickness are buried as much as three meters below the cone surface. Therefore, in several alluvial cones, and most notably in the one at the foot of watershed 10, we have a rather complete record of the erosional debris removed from the watershed during the past 8,000+ years. Study of these cones will give us information about long term processes and rates of erosion.

Preliminary observations indicate that alluvial processes with an average recurrence interval of perhaps once every one to three years have dominated the development of small watershed cones. The apparent contrast in the primary constructional processes for younger cones (annual scale events) and older ones (catastrophic debris torrents) derive from differences in watershed characteristics or from a change in the dominant geomorphic processes about 8,000 years ago due to changing vegetation and climatic regimes in post-glacial times. A further complication is that the older cones probably do not preserve a record of much of the alluvium carried in sediment transport events of low and moderate magnitude. Most of this material appears to have been transported directly through the stream channel cutting across the cone surface. However, there are a number of reasons for believing that larger watersheds may be more susceptible to massive debris torrent events. One factor is that longer channels offer greater chance for the development of debris jams which may trigger debris torrents and also offer a greater supply of organic and mineral debris. Geological considerations may also be very important. Dyrness (1967) has shown that within the Andrews Forest there is a tendency for mass soil movements to occur at elevations between 610 and 800 m which is the zone of transition from predominantly deeply weathered and altered, unstable volcanoclastics below to relatively fresh lava flows above. The capping effect of flows may contribute substantially to landscape instability in the upper parts of larger watersheds. In addition, there may be meterological factors such as greater total precipitation and effective rainfall intensities, including snowmelt contributions, at higher elevations which would increase the chance of periodic debris torrent erosion in larger watersheds. At this time, we do not have sufficient data to evaluate these hypothetical effects.

CONCLUSION

The valley bottoms near the confluence of Blue River and Lookout Creek have been cut and partially refilled by glacial and fluvial processes. Glacial sediments are overlain by mainstream river gravels which form two distinct fluvial surfaces above the modern channels. Sediments on the upper terrace are topped by Mazama ash, indicating that this surface was abandoned by about 8,000 years ago. Alluvial cones from tributary watersheds have been constructed onto the terrace surfaces. The size, degree of dissection, and internal make-up of the cones is directly tied to terrace-floodplain width and watershed characteristics--especially area and relief. Cones at the mouths of large watersheds (approximately 40 to 150 ha) were constructed primarily by deposition from debris torrents before 8,000 years ago. Since that time these cones have been deeply incised by the tributary and main streams. In smaller watersheds, annual alluvial processes have been the dominant process of cone construction. Surfaces of many of these cones are still aggrading and the Mazama ash is buried up to several meters within them.

The purpose of this work has been to establish background information on the time scale of geomorphic development in the vicinity of five experimental watersheds. In a related project Randy Brown is now conducting a study of soil genesis on the various geomorphic surfaces. We are also surveying the volume of post-Mazama ash sediment deposited on selected alluvial cones in order to make some estimates of long term erosion rates.

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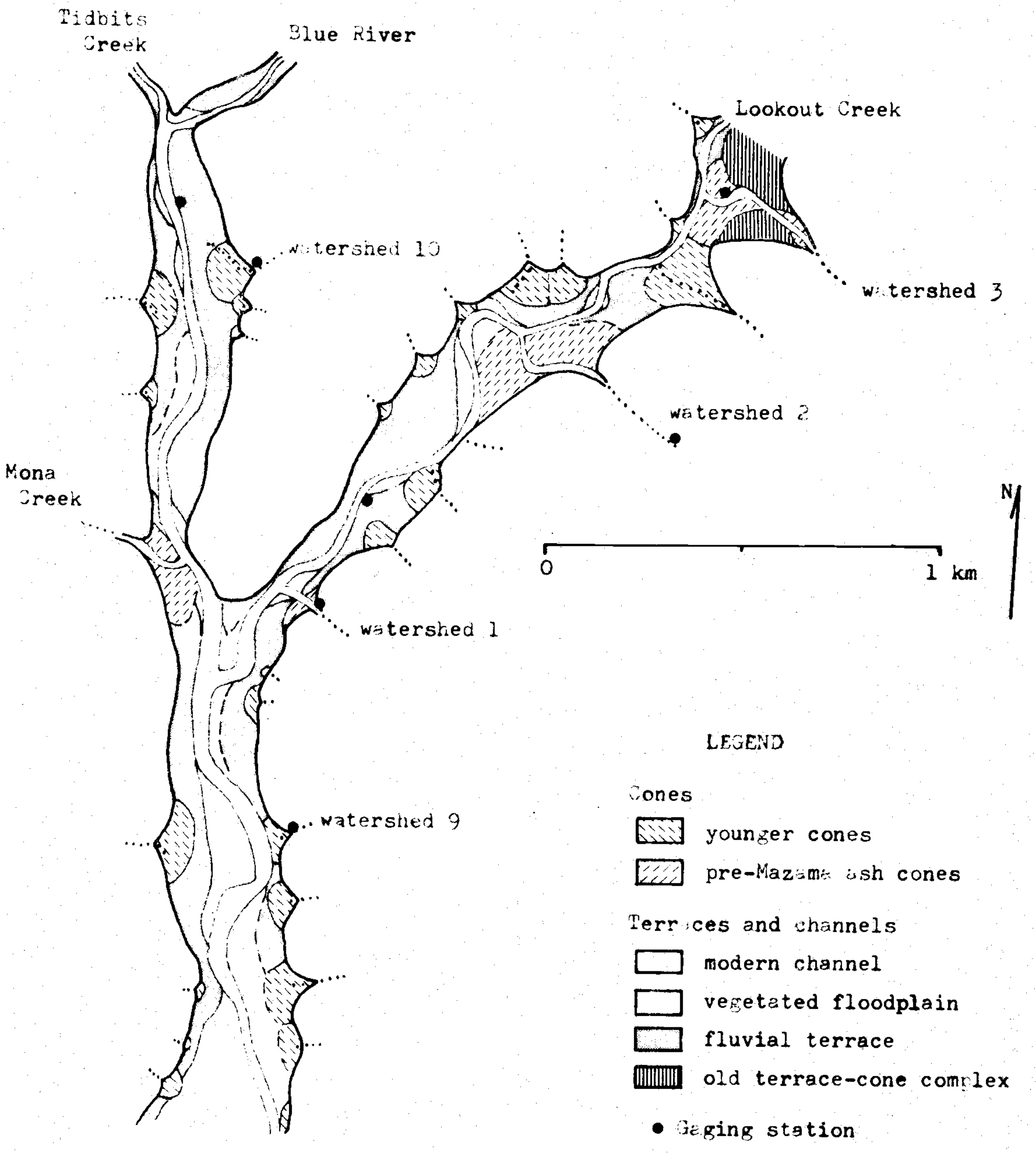

Figure 1. Map of geomorphic surfaces along Blue River and Lookout Creek.

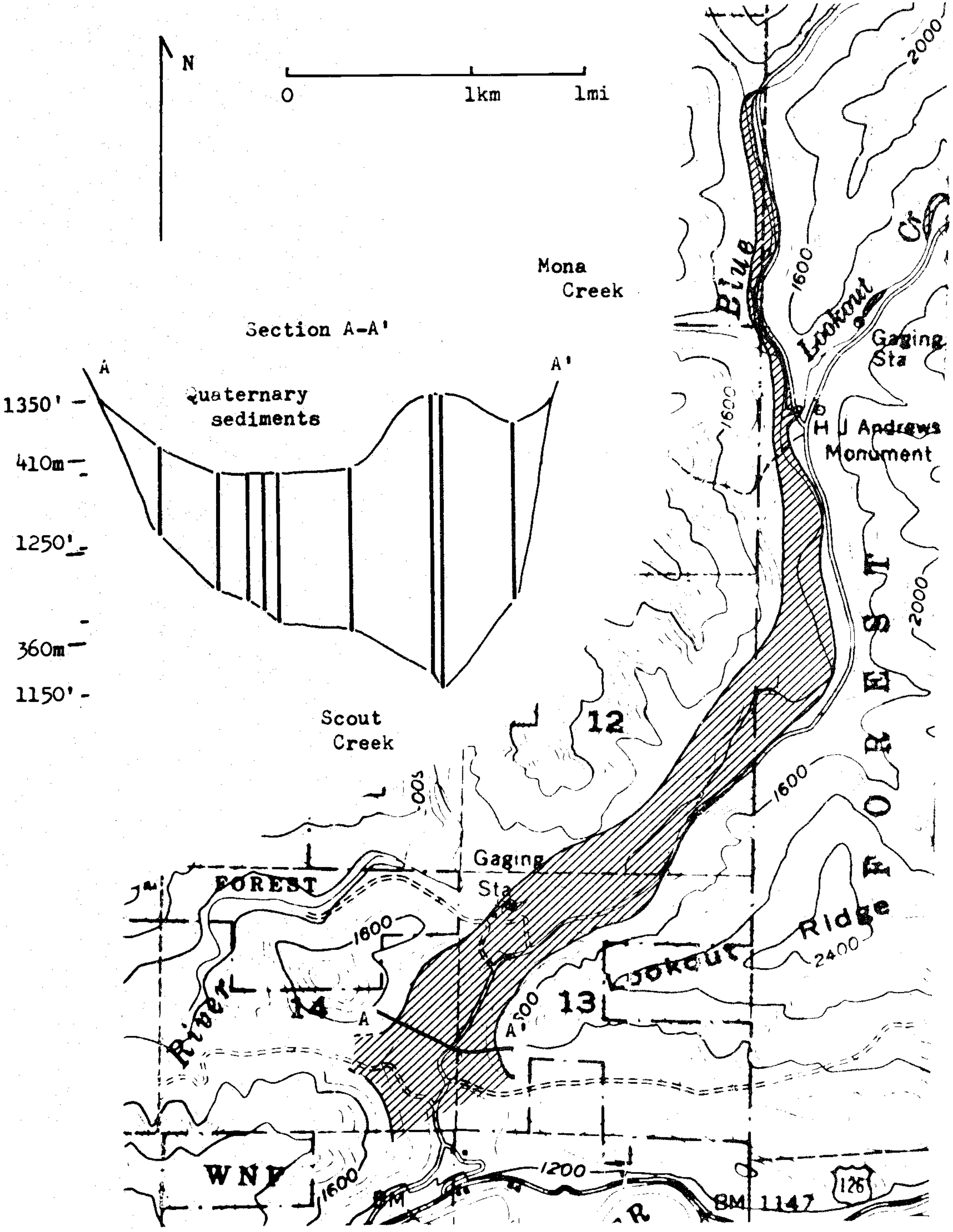

Figure 2. Distribution of valley bottom glacial sediments (shaded area) and cross section of Quaternary sedimentary fill in saddle dam area (A-A'). Drilling data on sediment distribution and depth are courtesy of G. Adams, U.S. Army Corps of Engineers. Base map is U.S.G.S. 15' Blue River Quad.

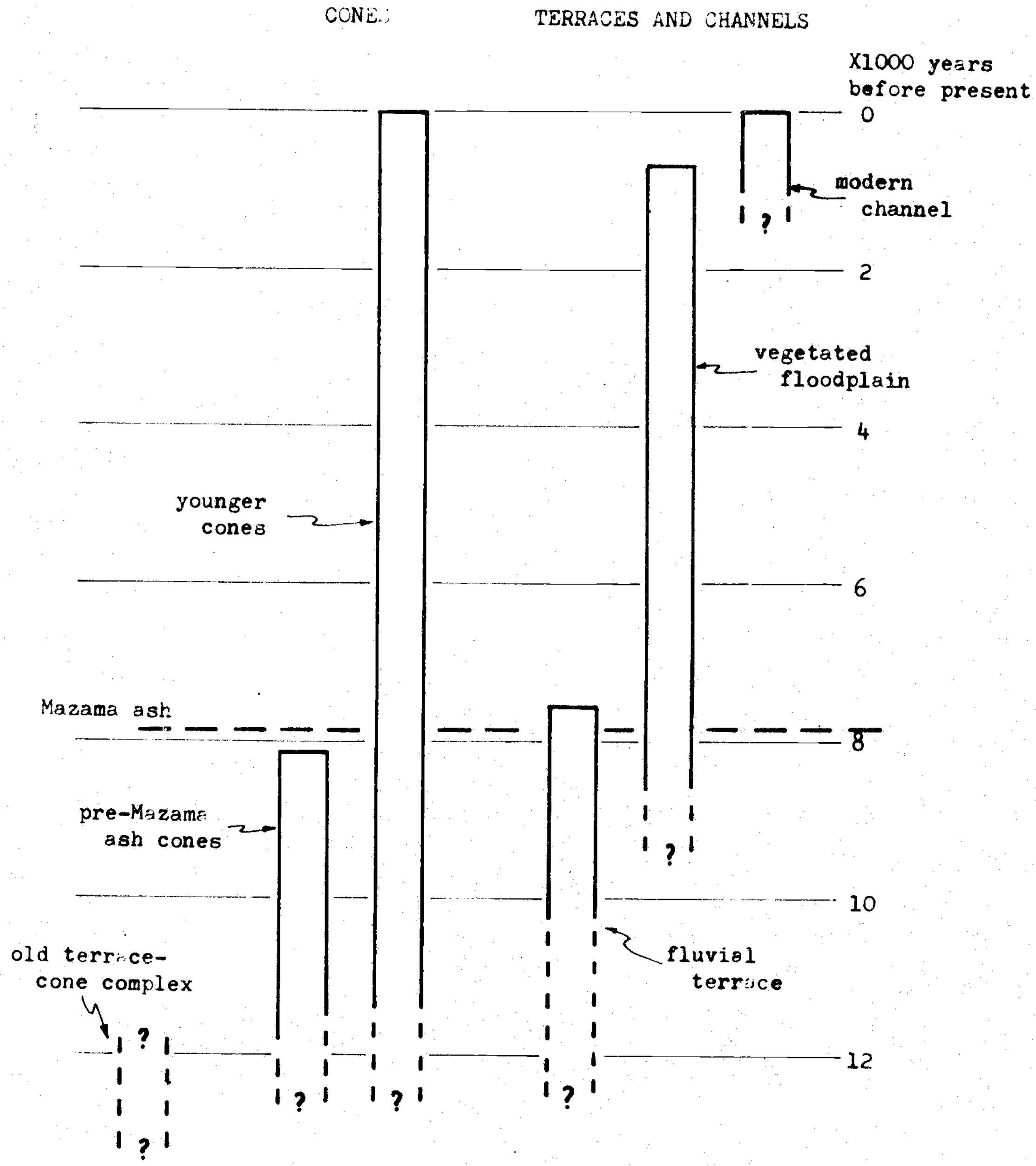

Figure 3. Temporal relationships of geomorphic units mapped in Figure 1.

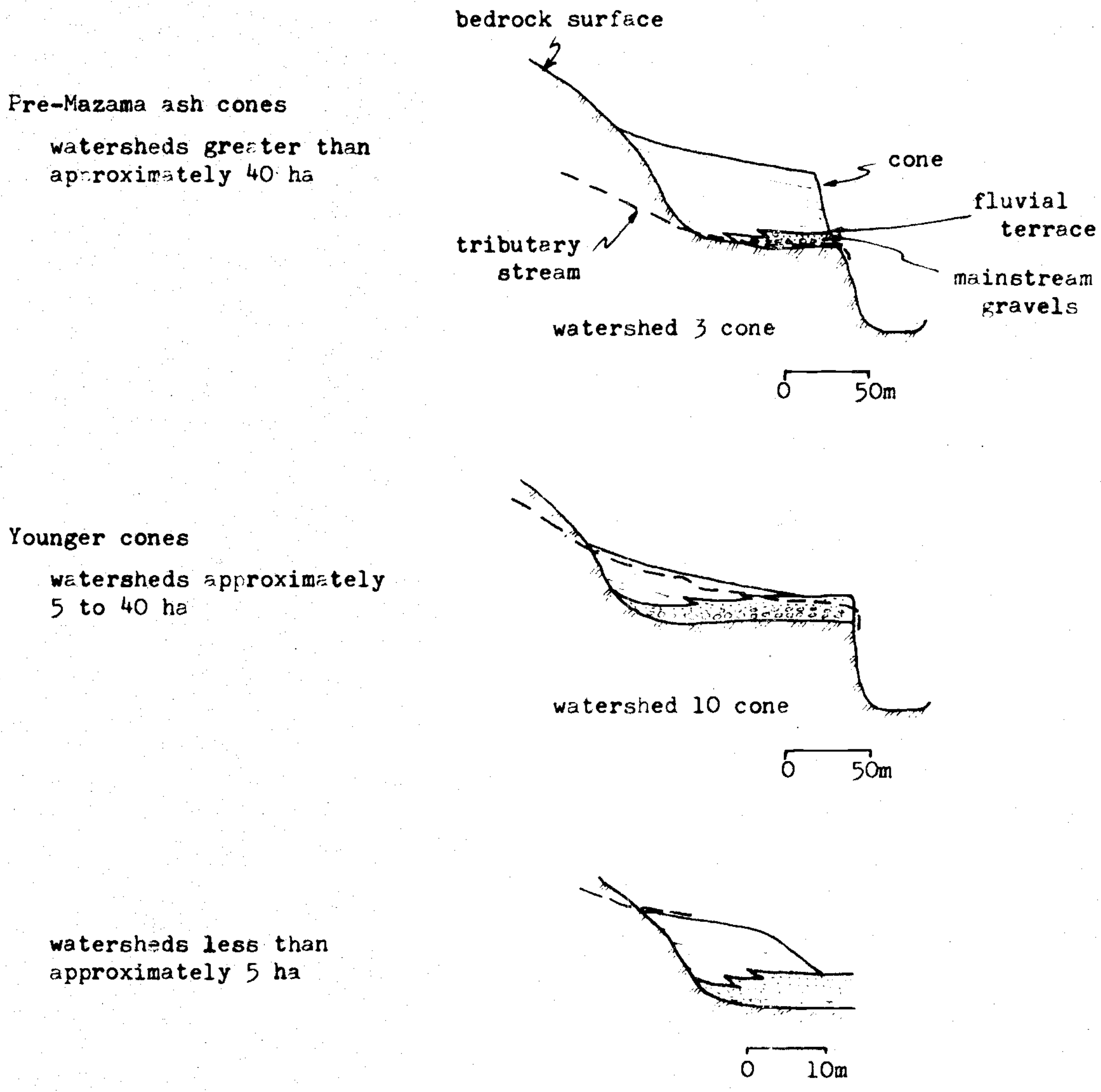

Figure 4. Schemetic radial profiles of three general types of alluvial cones.