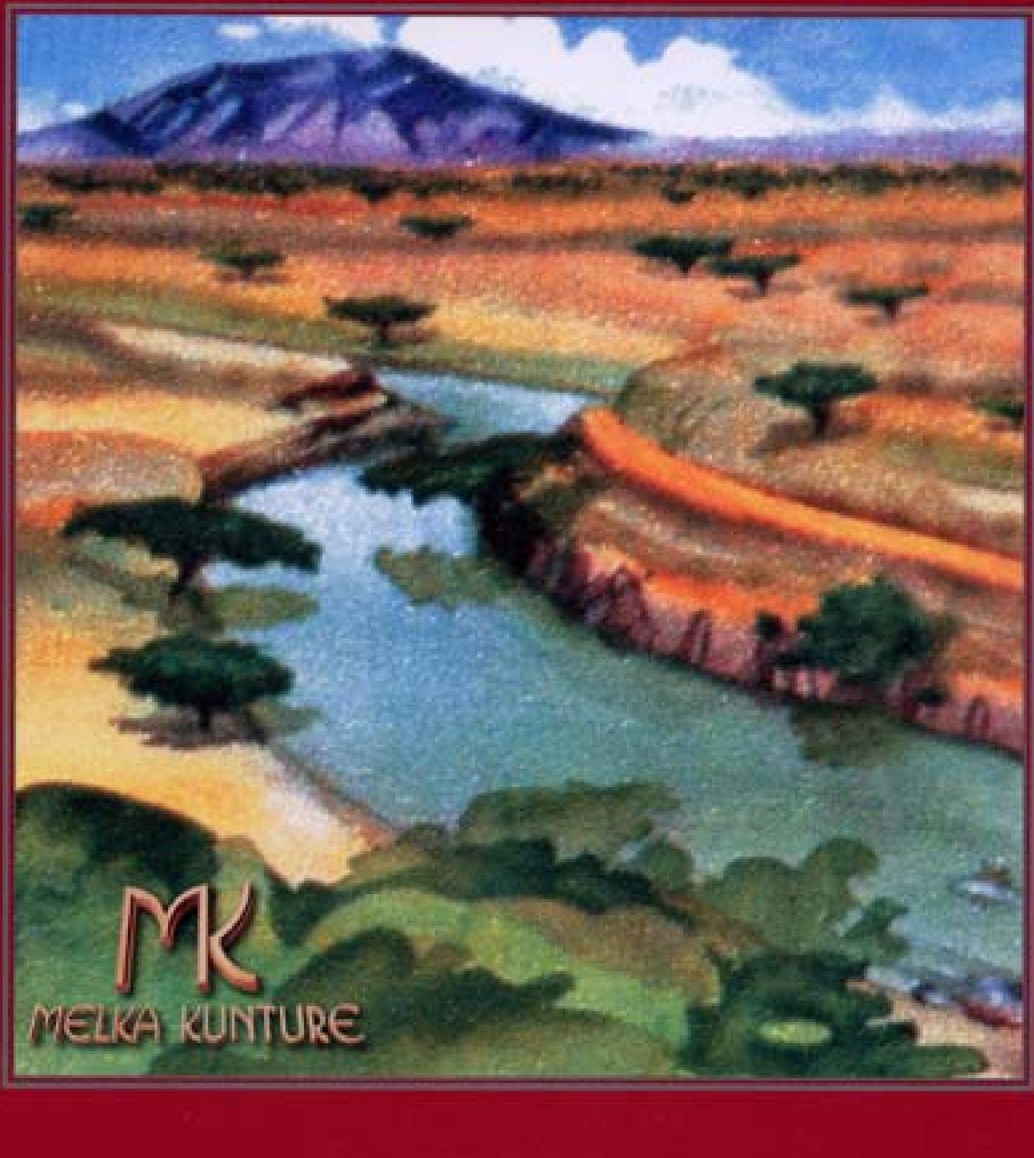
Edited by
Jean Chavaillon and Marcello Piperno

Studies on the Early Paleolithic site of Melka Kunture, Ethiopia



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Geology, volcanology and geochemistry

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Drainage pattern and regional morphostructure at Melka Kunture (Upper Awash, Ethiopia)

Guillaume Bardin[1], Jean-Paul Raynal[2], Guy Kieffer[3]

Melka Kunture depression belongs to the upper Awash basin. A village of the same name stands on the border of the Ethiopian Plateau, some fifty kilometres south of Addis Ababa (Fig. 1).

The basin surface is around 3000 km^2 and its altitude varies from 2000 to 2050 m. It is delimited by pliocene volcanoes the main ones being Wachacha and Furi in the north, Boti and Agoiabi in the south. Upstream, the basin is a collapsed plain and downstream a less collapsed zone of enclosed gorges (Taieb 1974). Its eastern limit is marked by the main graben of the Ethiopian Rift belonging to the large East-African rift system (Mohr 1999). The Melka Kunture area is made up of valleys with inner terraces of which have resisted erosion. The visible thickness of those deposits is around 30 m, but the total thickness of the various levels is about 100 m.

The Melka Kunture area shows dissimilar morphology between the right and left banks of the Awash River. On the left bank, the plain goes up to the Wachacha slopes as rather regular glacis (Fig. 2), while the right bank shows a series of steps linked to a compartmentation formed by a Northeast-Southwest fault system. This segmentation affects the series of less collapsed compartments separating the Melka Kunture region from the rift graben.

Tectonic evolution of the Melka Kunture area determined the sedimentation and the morphological types. This evolution still develops today. The Holocene topography, regularised in wide glacis, is in complete imbalance with flows responsible for vigorous incisions and fast destruction of the pedological and vertisolic cover.

A morphostructural analysis (Bardin 2000) based on topographic maps was used (Howard 1967; Prud'homme 1972; Griboulard and Prud'homme 1987; Collina-Girard 1989; Collina-Girard and Griboulard 1990). This technique considers base maps as useful objects that can reveal quite subtle morphology. Its aim is to extract the best possible information contained in cartographic documents, which must be the basis of any geographical, geological or geomorphological study.

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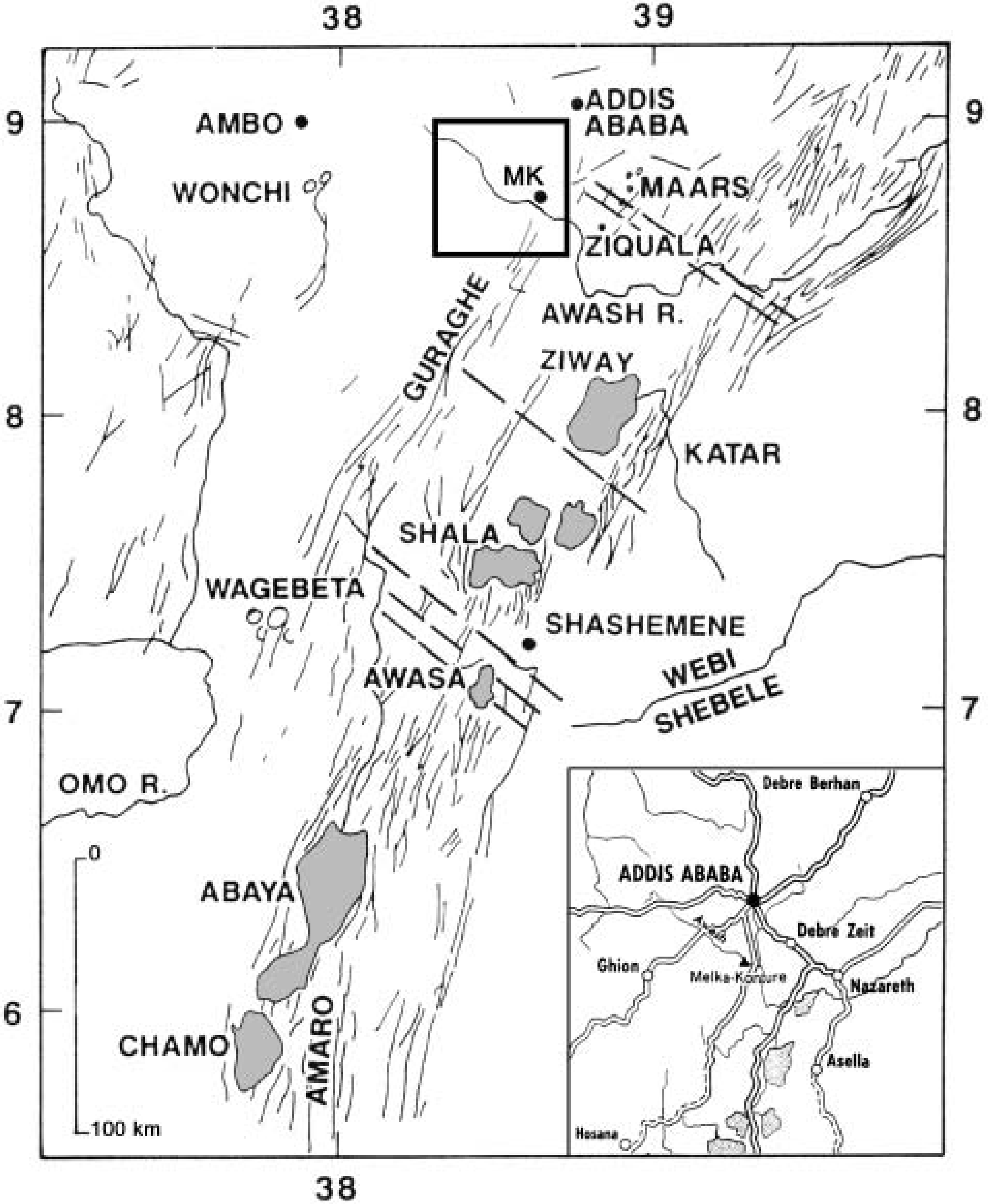

Fig. 1. Location map (after Woldegabriel *et al.* 1990).

Fig. 2. The Wachacha and its southwestern slopes. *Cliché J.-P. Raynal*

The regional drainage pattern

The regional drainage pattern is characterised by its heterogeneity but several different zones can be distinguished (Fig. 3). We use the classification of Howard (1967).

Zone 1 is characterised by a physiographical pattern of *radial* type. This configuration is linked to the presence in the zone of quaternary volcanoes such as Wachacha, Furi, and Wato Dalecha Mount. The drainage density is high.

In zone 2, the drainage density is low and we notice flow convergence zones as for example the Dilu or Haro-Dila plains, characterised by a *centripetal* pattern. In these intensely cultivated plains, many irrigation ditches have been built. Mount Debel is revealed by a regional drainage pattern of *radial* type. In this zone, the main river, the Awash, expands as it emerges from the Dilu plain and flows towards the south-east.

Zone 3 presents a high drainage density, with a *dendritic* pattern, one part of which converges towards the Aba Samuel Lake, another towards one of the Awash River's large tributaries, the Atebella River, and a third towards the Awash River itself. The Awash River in the south and Wachacha, Debel and Furi volcanoes in the north mark its limits. The Awash River delimits zone 3 and 5. It still is the main drainage and flows east and southeast.

In zone 4, the pattern is organised in parallel sets flowing towards the north-west. This time, the Awash River is not the main drain, but the Watira River, which flows towards the north-east.

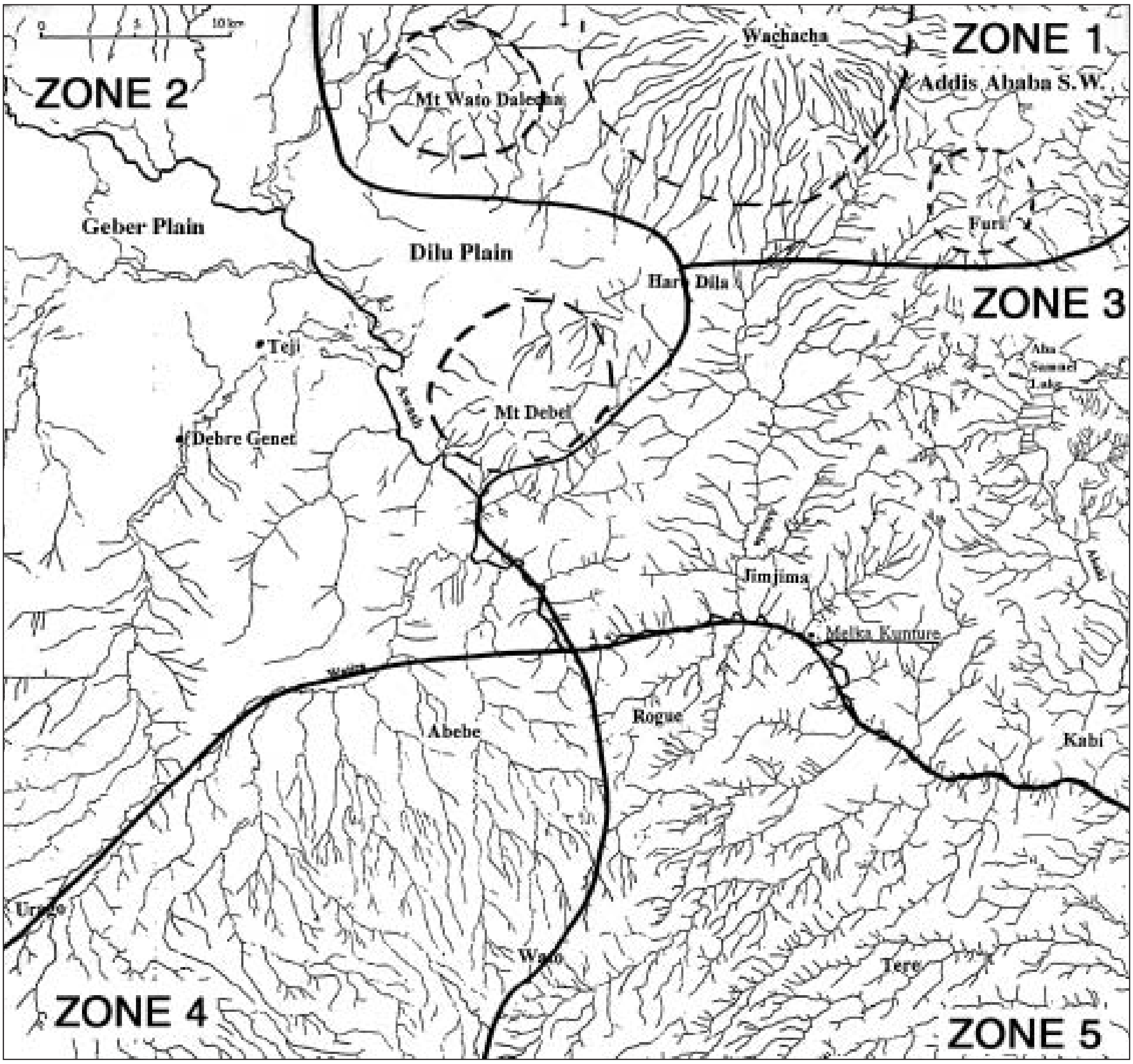

Fig. 3. Subdivisons of the regional drainage pattern.

In zone 5, fluviatile networks are of *flat lattice* or *directional lattice* type with a main orientation towards the north-east, forking towards the southeast, and lying on the right side of a line passing through Bedesa and the exit of the Awash gorges.

In conclusion, the regional drainage pattern of the studied zone is defined by the large variety of its graphic characters. These take into account the topographic and geological structures and bring to the fore a dissimilarity between the morphology of the right and left banks of the Awash River. This is evidenced by a pattern of main drainage preferentially directed towards the northeast-southwest on the right bank and by a pattern more dependant on the topography (flowing on the slopes of quaternary volcanoes and convergence towards the plains) on the left bank. The Awash River is the main drainage feature. It flows either from west to east or northwest to southeast. Most of its tributaries flow in directions almost orthogonal to its route. Dilu, Geber and Haro-Dila plains are grouped on an east-west line. They also function as reservoirs (convergence zones of the flows) and as a source of river supplies. The Awash River increases its strength as it flows through these plains.

Repartition and orientation of preferential directions, of obstacles to drainage and of straight sections

This method postulates that surface drainage patterns are strictly dependant on the substratum anisotropy (faults, synclines, deep anticlyne). It highlights major directions of drainage, straight parts or abrupt changes of direction directly caused by obstacles in the drainage lines. The distribution and orientation are studied and help to characterize major structural directions which can be linked with the history of faulting.

Several preferential structural directions emerge (Fig. 4):

- An important W to E direction (N 90°)
- A NE-SW direction (N 45°)
- A NS direction (N 180°)
- A NW-SE direction (N 130°-140°)
- A SSW-NNE direction (N 22°)

Among these, we find again the two directions, which seem to guide the Awash River: N 90° and N 130°-140° and the N 45° direction. These directions are probably linked to a structural control of surface flows. They follow fault lines and fractures corresponding to different evolutionary phases of the Ethiopian Rift. We can link the N 90° direction to the W-E tectonic line crossing the Ethiopian Plateau close to N 9° latitude (Ambo lineament). This structural direction coincides with the alignment of the Wato-Dalecha and Wachacha volcanoes. It is likely that the N 130°-140° direction influenced the cutting of the gorge of the Awash River. The N 45° direction is probably linked to a period of more recent structural alteration within the Ethiopian Rift. This period of tectonic activity affected the right bank of the Awash River, giving a structure with the appearance of toppled blocks. The formation of fault steps on the SE border of the

Fig. 4. Orientation of preferential directions, of obstacles to drainage and of straight sections.

Melka Kunture basin builds the latter into a half-graben. We also observe fault steps at the exit of the Awash gorges. These steps announce the arrival in the main graben of the Ethiopian Rift.

Study of the envelope surfaces

The method consists in retracing the contour lines without accounting for thalwegs or valley line floors. Thus, we obtain a theoretical surface that corresponds to the topographic image before the development of the incision processes. Using a 1/50000 map, we do not include thalwegs under 3 (Collina-Girard 1989).

This representation brings to the fore the sub-rectilinear and oriented nick-points, indicating structural directions. Transferring these characteristic lines to tracing paper, we obtain a basic structure of the anisotropies of the sedimentary cover. In practice, this technique encounters the constraints of cartographic documents namely scales and the of contour line interval that affects the plotting precision. In the present case, the contour line interval on the 1/50000 map of Melka Kunture is 20 metres. For some areas with low differential relief, an interval of ten metres would allow a more refined plot.

We have limited this study to the Melka Kunture map alone, which seemed the most representative. We can observe simultaneously the stepped border leading to the rift graben and the gorges upstream of the Melka Kunture basin (Fig. 5). Oriented nick points (little visible directly on the 1/50000 map) certainly betray geological anisotropies of tectonic origin. Actually, these nick-points are oriented and organised following preferential directions.

We can see a network of structural directions converging towards the NE. This network has segmented the Awash gorges. A structural line passes where the Awash enters into the gorge rather than at the alignment of the Melka Kunture fault, as we observed on the field. Several structural directions cross the Awash gorges creating nick points or changes of direction of its course. The exit of the gorges also corresponds to several structural directions. They produce the series of successive steps at the SE border of the raised tectonic block separating the Melka Kunture basin from the main graben of the Ethiopian Rift.

Longitudinal profile of the Awash River

Producing a longitudinal profile aims to bring to the fore the equilibrium or desequilibrious state of a river. It allows one to follow the river's evolution in accordance with its altitude and to gather limits of elevations that correspond with tectonic anisotropies or with size limits for various blocks. According to the variations in depth of the river in the bedrock, one can deduce the nature of the rock, different sediment types, differential erosion or calcareous marls etc.

From upstream to downstream, we can divide the profile into four parts, of which only the fourth has a profile close to equilibrium (Fig. 6). We notice important nick-points at kilometres 56 and 70. In the first part of the profile, the Awash flows on a hard surface, probably eruptive rocks. Then, we observe an abrupt threshold, as if the river reached a more collapsed tectonic block constituted of the same rocks. At the commencement of the gorges, the Awash is suddenly enclosed in the substratum, firstly coming up against hard volcanic roots (small volcanic blocks of Muti and Tinishu Muti and a lava lake) and against the front of the quaternary lava flows (Fig. 7). This explains the rounded and irregular aspect of the profile. From kilometre 75, the profile regularises.

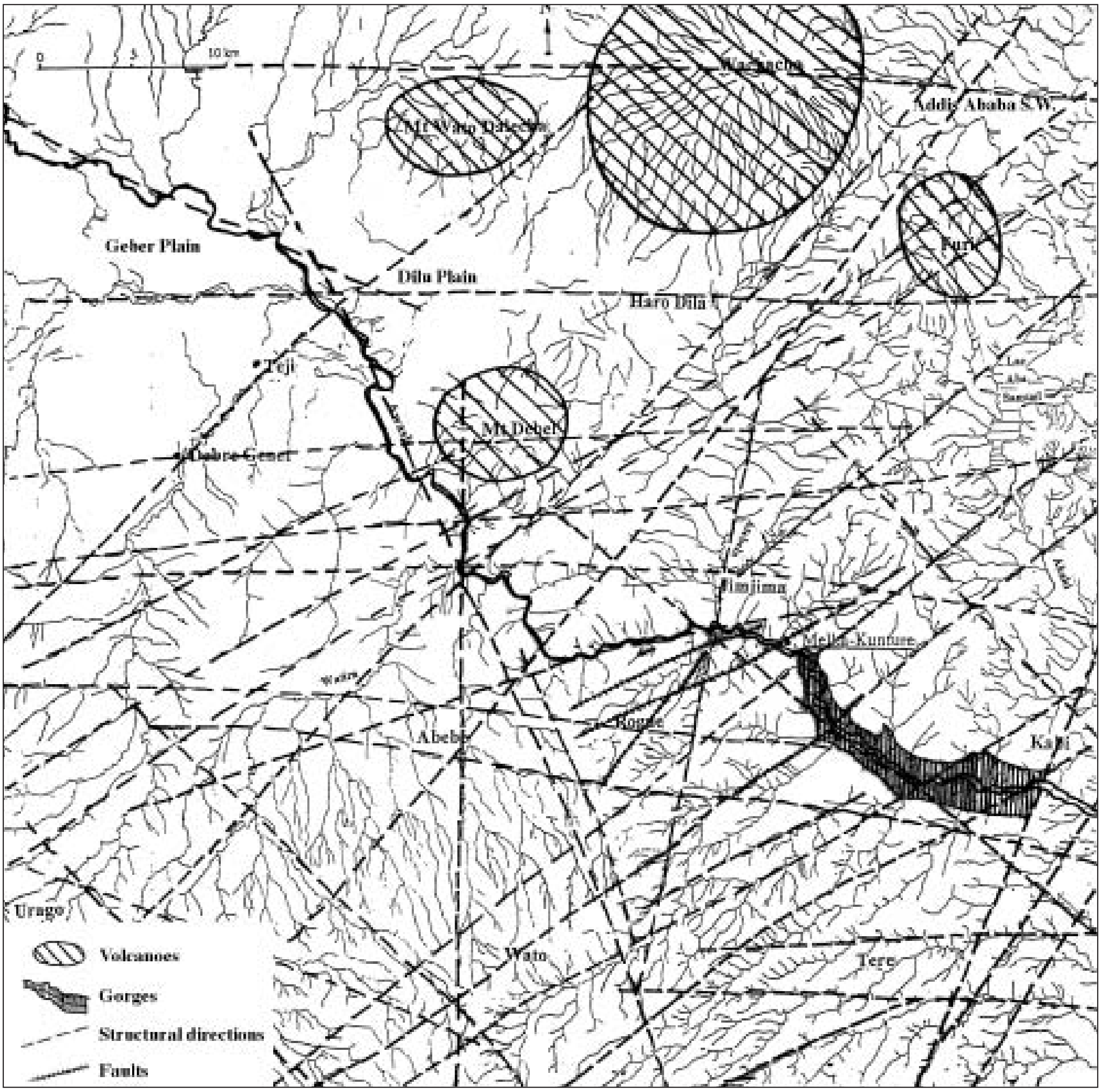

Fig. 5. Study of the envelope surfaces.

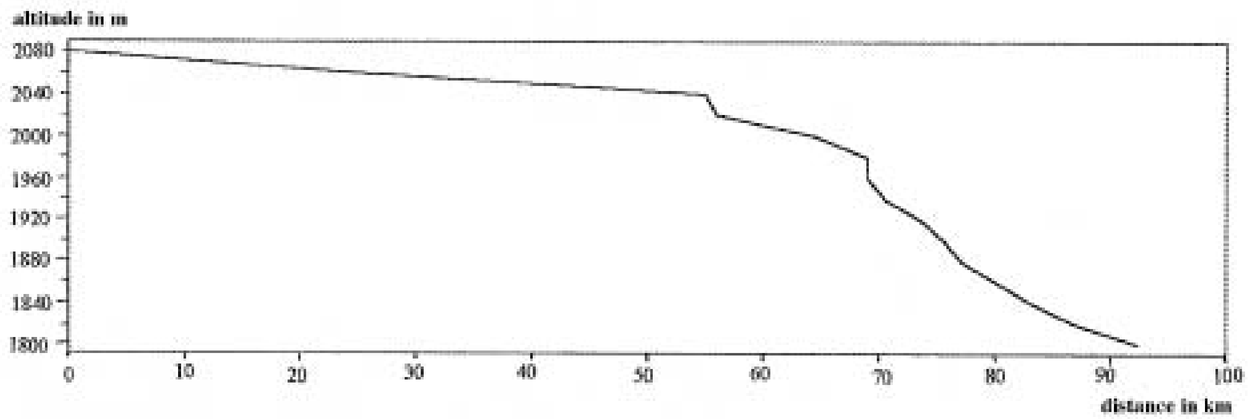

Fig. 6. Longitudinal profile of the Awash River.

Fig. 7. Awash River gorges and Tinishu Muti volcano in the background. *Cliché M. Hirbec-Raynal*

Structural sketch of the Melka Kunture region

The results of the morphostructural analysis and photo-interpretation allow us to build a structural sketch of the Melka Kunture region (Fig. 8). From the characteristics of the drainage pattern, it has been possible to determine structural directions coinciding with those obtained with the study of envelope surfaces.

We find again the tectonic lines of W-E direction on which the Wato-Dalecha, Wachacha, Furi and Debel volcanoes are aligned (Ambo lineament). These volcanoes perhaps appeared because of such faults during an ancient tectonic phase, corresponding with the commencement of the Ethiopian Rift event. This direction is still seismicaly active (Gouin 1979). As well, flow convergence zones follow those structural directions.

The NW-SE directions, which characterizes transverse faults zones in the Main Ethiopian Rift, are posterior to the tectonic phase that gave rise to the W-E faults. These NW-SE directions determine the course of the Awash River, and notably its gorges.

The SW-NE directions correspond to one or more tectonic phases posterior to those responsible for W-E and NW-SE directions. These faults formed the SE border of the Melka Kunture basin as a half-graben (Figs. 8, 9). The Melka Kunture fault belongs to the northern part of the Guraghe major border faults stepped system in this western part of the Main Ethiopian Rift. Between the SE border of the basin and the toppled blocks forming the main graben of the rift, stands a raised block, which the Awash encloses. This block is crossed by a network of structural lines converging towards the NE. One of those lines caus-

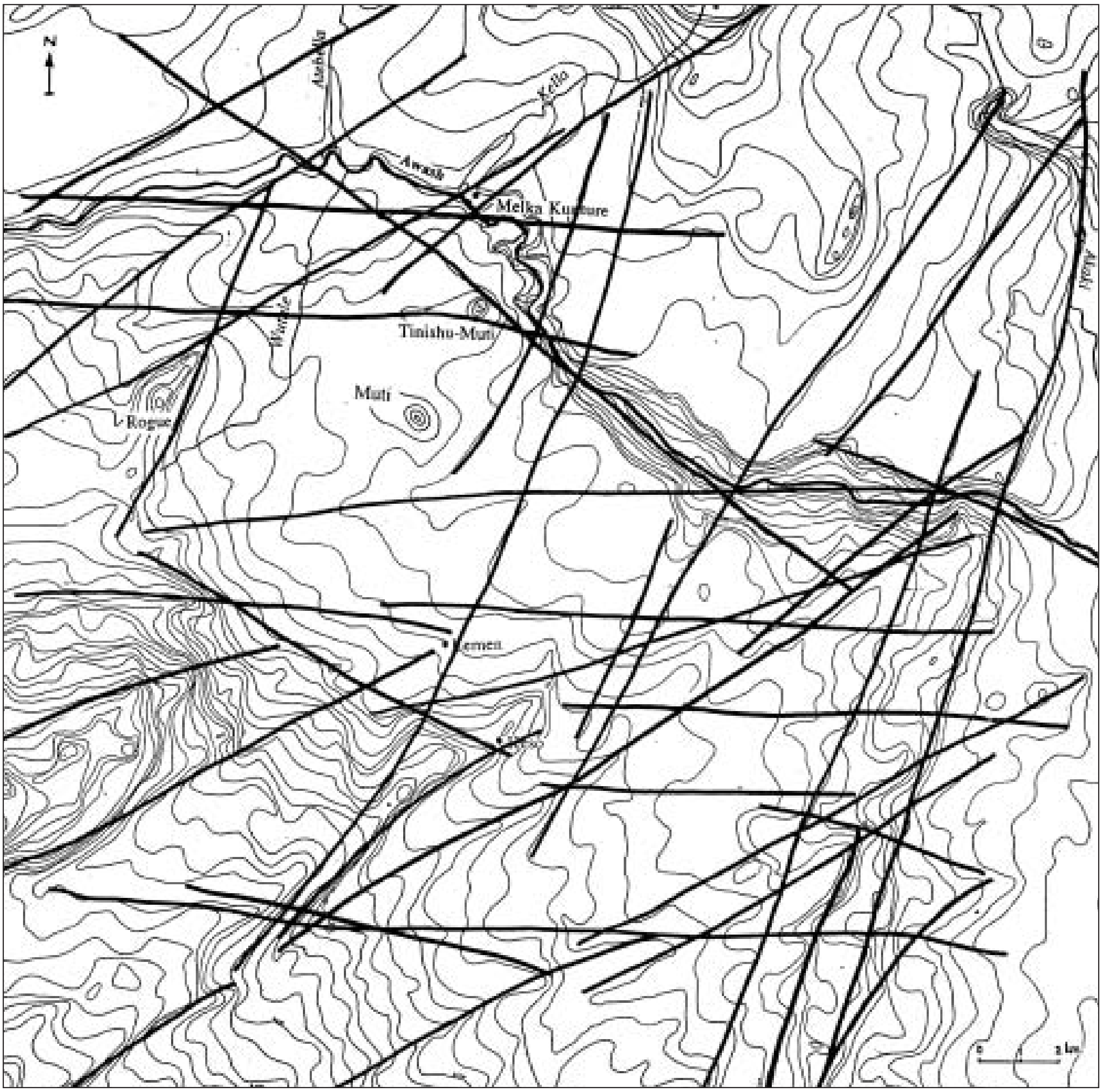

Fig. 8. Structural sketch of the Melka Kunture region.

es the initial formation of the gorge and another finishes the incision. Actually, as we can see in the field, the gorges do not begin immediately at the Melka Kunture fault level, but further afield at the level of another structural line.

The Awash River, which is the main actor in the play of sedimentation in the Melka Kunture basin, gained most of its structural characteristics during the oldest tectonic phases (WE and NW-SE structural directions) different to those producing the structural directions that control the majority of surface flows (SW-NE direction). This can easily be seen on the right bank of the Awash River. At the time of its entrenchment, the Awash River certainly took advantage of an ancient NW-SE fault, which explains the general orientation of the gorges. At their commencement, the river came up against hard volcanic roots (namely a lake of aphyric lava) and against the front of quaternary lava flows. This explains the sudden nick-points visible on the longitudinal profile. At the contact with softer rocks, the profile regularises.

Fig. 9. SW-NE border fault at Godeti. *Cliché G. Kieffer*

Future research and new geological and geochronological information will bring more detail about the structural evolution of the Melka Kunture basin and its relationships with the Main Ethiopian Rift tectonic history.

Maps

- 1/250000: Akaki Beseka (Ethiopia) by Ethiopian Mapping Authority. EMA series, sheet NC 37-14, edition 2.
- 1/50000: Addis Abeba SW, Melka Kunture, Bantu and Teji, SMD 4 (DOS 450) series, sheets and editions: 0838 BI; 1 SMD/DOS 1973, 0838 B3; 1 SMD/DOS 1975, 0838 A4; 1 SMD/DOS 1975, 0838 A2; 1 SMD/DOS 1975. published by the Ethiopian Government's Ministry of Land Reform and Administration (Survey and Mapping Department).

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