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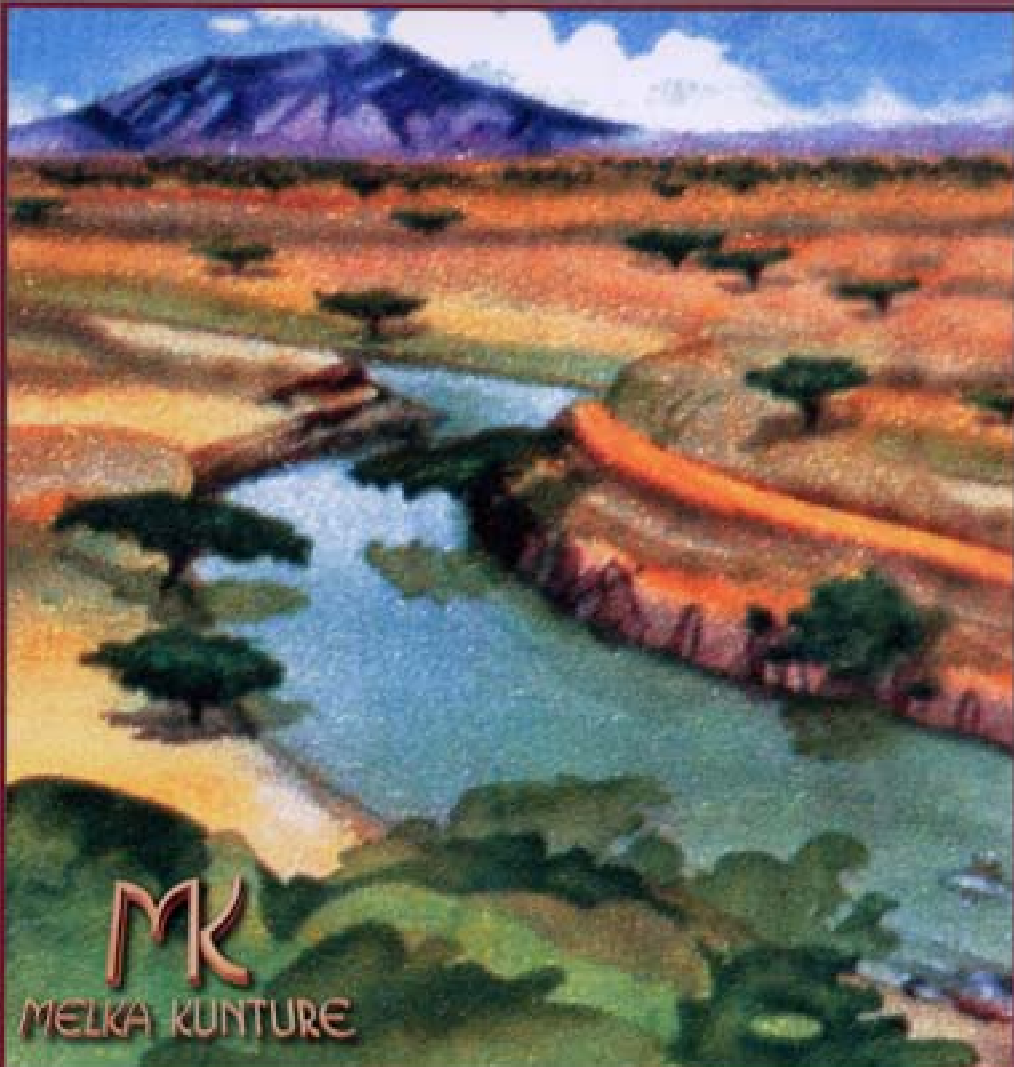


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# Geology, volcanology and geochemistry

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# Trace element geochemistry in Balchit obsidian (Upper Awash, Ethiopia)

Gérard Poupeau[1], Guy Kieffer[2], Jean-Paul Raynal[3], Andy Milton[4], Sarah Delerue[1]

Obsidian is a large component of some lithic assemblages discovered in the sites of Melka Kunture. A major source of obsidian is located at Balchit, close to Melka Kunture. A first study of the Balchit area was conducted in 1973 by P. Soulier (Chavaillon 1976b, c; Soulier 1976) while preliminary analyses were performed on obsidian artefacts discovered in Late Stone Age assemblages of Wofi III (Hivernel 1976; Hivernel-Guerre 1976).

Since 1999, new investigations have been undertaken on the volcano-sedimentary environments of Melka Kunture (Kieffer *et al.* 2002). In 2003 analyses was performed on several obsidian samples from various locations, both *in situ* lava of Balchit and reworked debris or pebbles from different alluvial formations of the Awash River and its tributaries.

### Location and brief description of the outcrop

The little obsidian massif of Balchit belongs to the Pliocene rift margin silicic centers of the Wachacha Formation, located on the western border of the Main Ethiopian Rift, in the Addis Ababa Rift Embayment. It is located 25 kilometres South-East of Addis Ababa and seven kilometres North-East of Melka Kunture (38° 38’ 19” E, 8° 45’ 16” N), on the left interfluve of the Awash River (Fig. 1). Recently, its age has been established at 4.37 ± 0.07 Ma by K-Ar measurements (Chernet *et al.* 1998). Other obsidian lavas from the Main Ethiopian Rift have more or less similar ages at Bora At (4.53 ± 0.23 Ma) and Asebot (5.23 ± 0.24 Ma; Woldegabriel *et al.* 1992).

Obsidian in primary position is not very easy to locate. The outcrop is mainly revealed by huge flaking areas where cores, waste flakes, blades and debris (Fig. 2) have accumulated on several thousand of square

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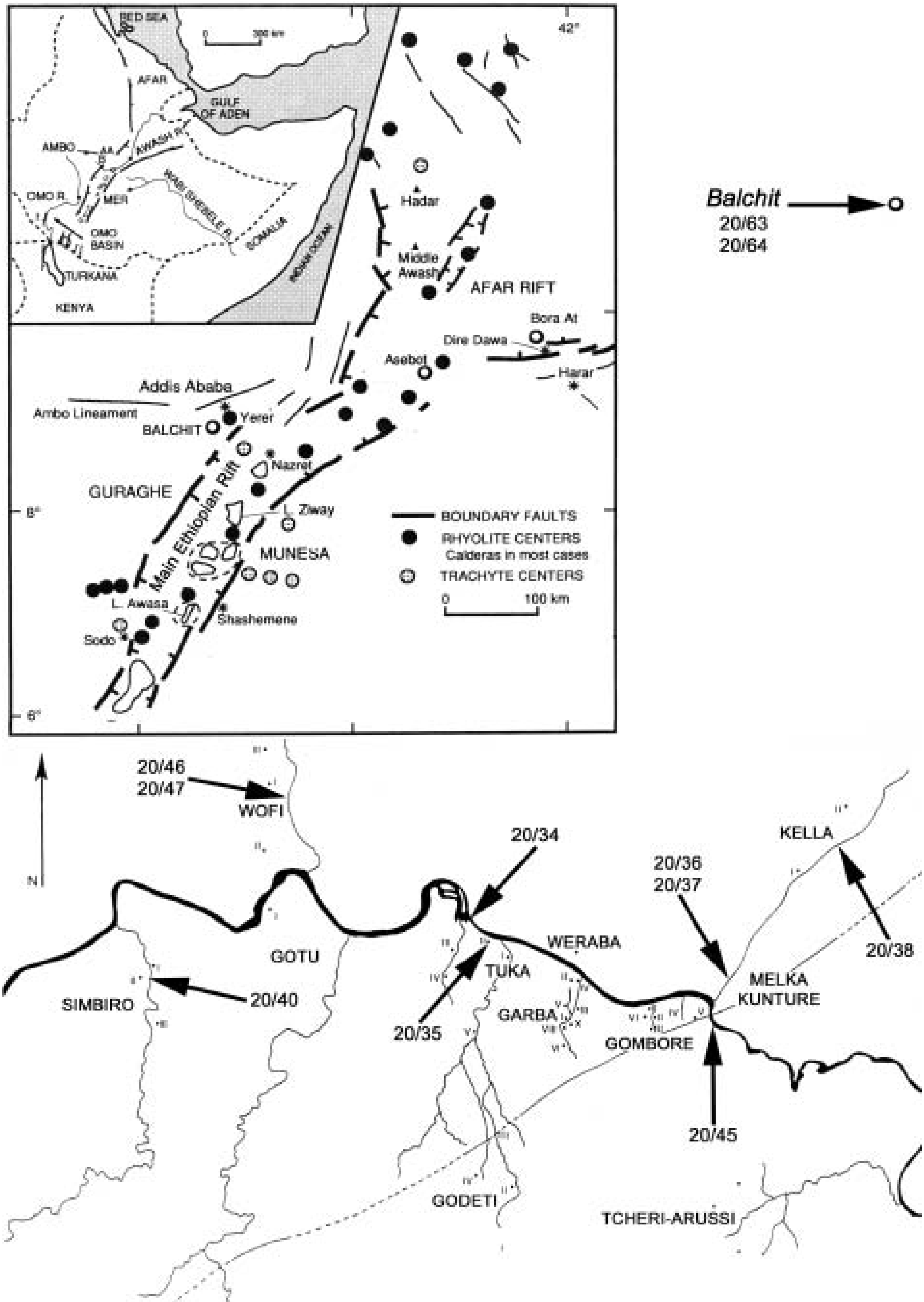


Fig. 1. Map showing location of the Balchit obsidian outcrop and sampling localities (general setting after Woldegabriel *et al.* 1992; local map after Chavaillon).

Fig. 2. Close-up view of obsidian artefacts. *Cliché G. Kieffer*

Fig. 3. Accumulation of obsidian artefacts and debris. *Cliché G. Kieffer*

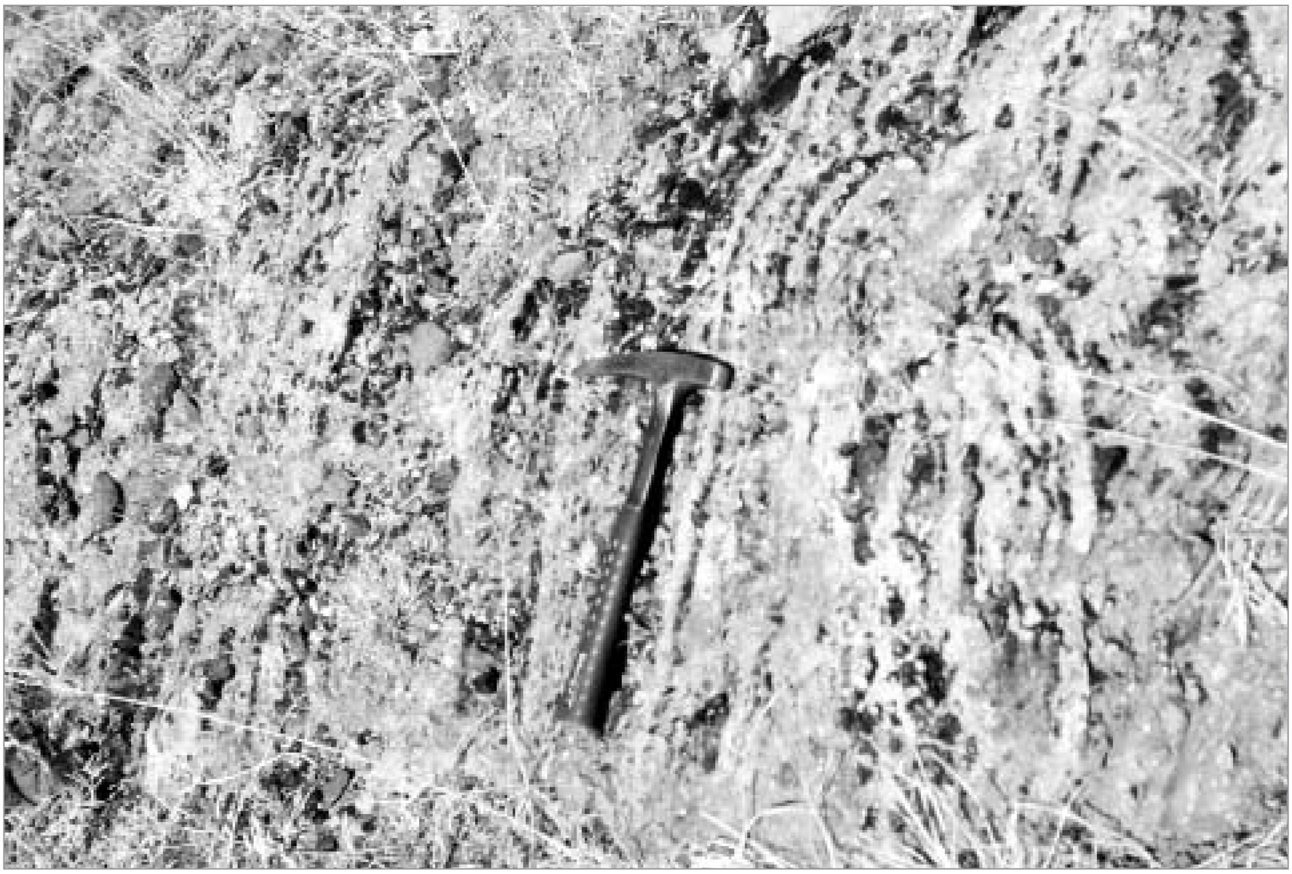

Fig. 4. Vertical fluidal structure. *Cliché G. Kieffer*

Fig. 5. Perlitic lava. *Cliché G. Kieffer*

Fig. 6. Weathered lithophysae. *Cliché J.-P. Raynal*

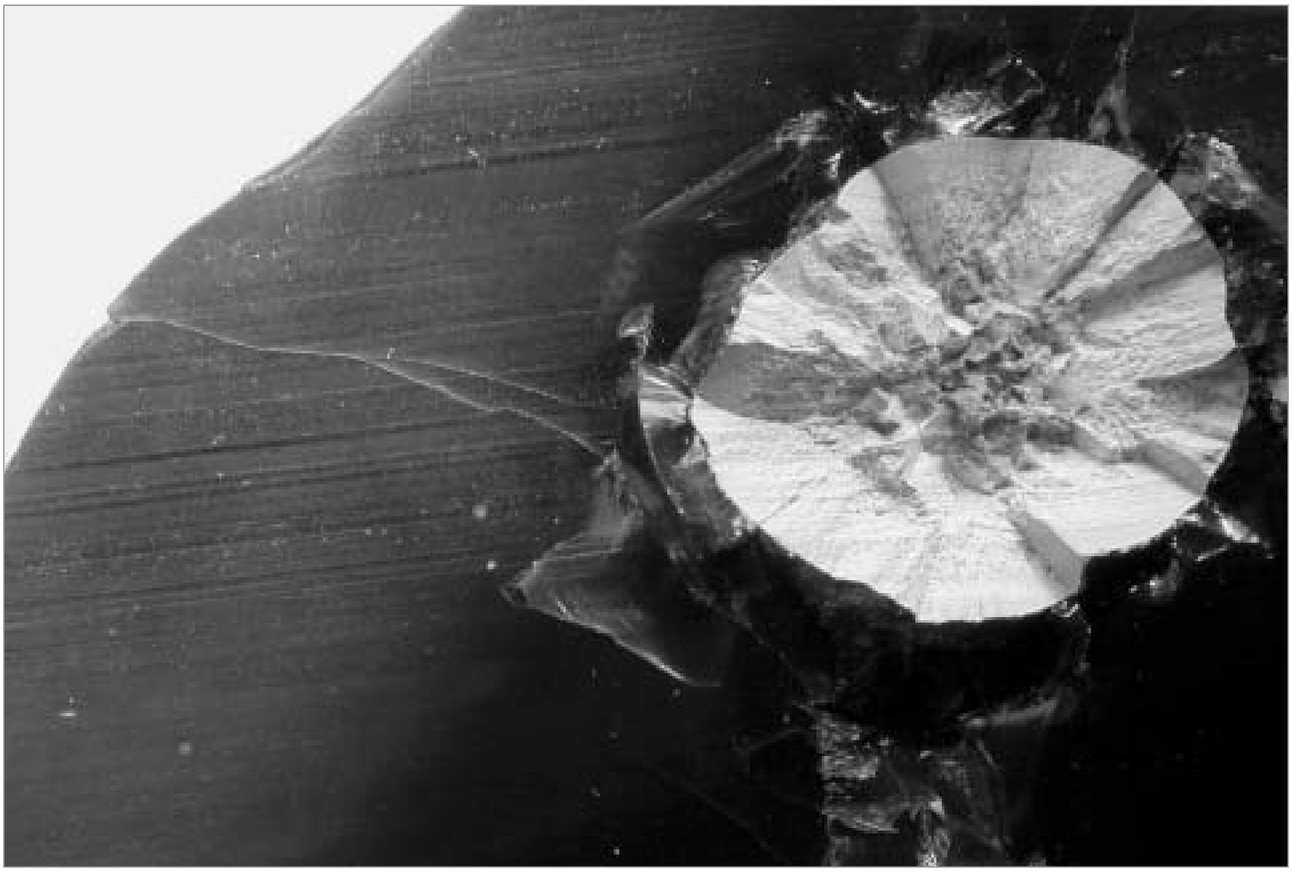

Fig. 7. Original banding of obsidian preserved in devitrified spherulite. *Cliché J.-P. Raynal*

Fig. 8. Unweathered massive black obsidian.
*Cliché J.-P. Raynal*

metres between prehistoric and present times (Fig. 3). It is therefore difficult to give an accurate structural interpretation of this eruptive formation and its limits. The morphology itself is not very explicit, consisting of a flat hill not very evident in the landscape; it could indicate the presence of a flow, but is more likely a flat dome-flow.

The formation is better exposed at the north-northeast limit of the outcrop, in a gully a few metres deep. A well developed fluidal structure, almost vertical (Fig. 4), could possibly indicate an extrusive flowage or represent ramp structures in a flow. Perlites (Fig. 5) and greyish to white lithophysae (Fig. 6) are abundant in a sometimes perlitised finely banded lava; the lithophysae are either spherulithic growths of feldspar or devitrified glass in which the original banding of the lava is still visible (Fig. 7). Beautiful amygdals and decimetric lenses of pure and massive obsidian are preserved among the weathered rock (Fig. 8).

When unweathered and thus selected for flaking, the lava is massive, appears uniformely black but is very finely banded, breaks easily with conchoïdal fractures and gives more or less translucent flakes with excellent cutting edges.

**Sampling**

Two samples were taken in the fresh lava on Balchit outcrop (MK 21/63 and MK 21/64) and nine other samples from alluvial deposits of the Awash River or its left bank tributaries, except for one coming from the Simbiro section on a right bank tributary (Fig. 1):

| | |
|---|---|
| MK 20/34-2: | Melka Garba Crossing, active sand and gravel bar |
| MK 20/35-5: | Melka Garba Crossing, old alluvium under ash-flow tuff |
| MK 20/36: | Kella, creek bed |
| MK 20/37: | Kella, recent alluvium |
| MK 20/38: | Kella, old alluvium |
| MK 20/40: | Simbiro, old alluvium between archaeological layers |
| MK 20/45: | Awash Gorge, minor bed |
| MK 20/46-3: | Atebella, old alluvium |
| MK 20/47-1: | Atebella, recent alluvium |

More samples have been collected but not yet analysed.

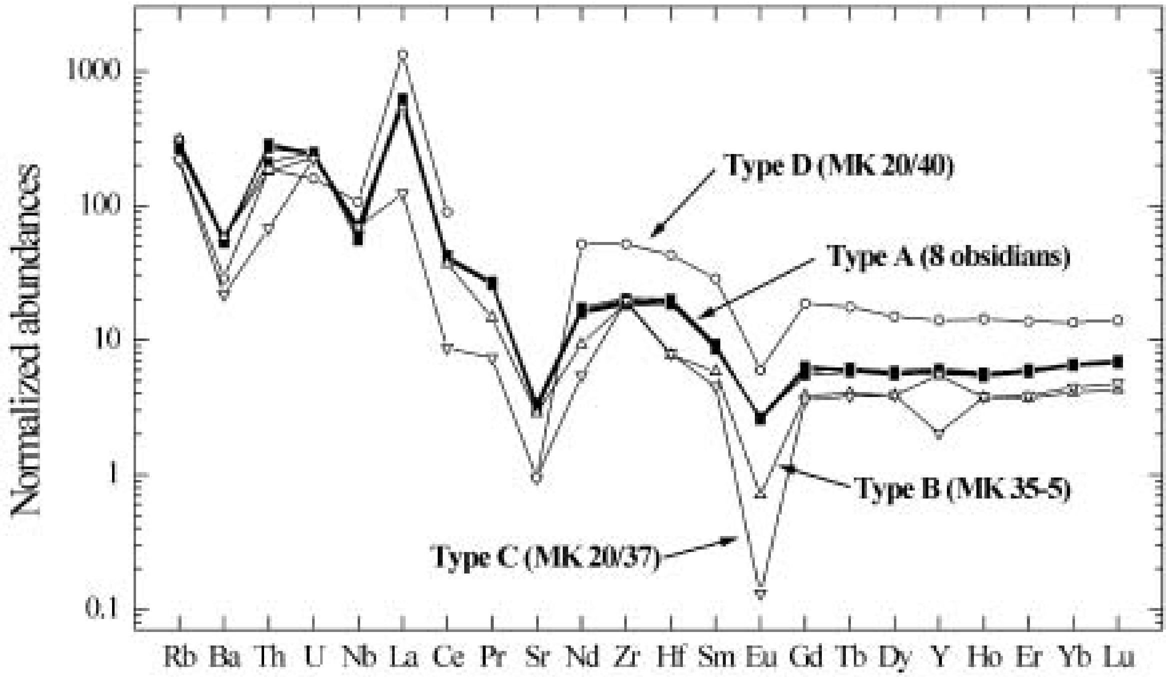


Fig. 9. Normalised abundance of trace elements in Melka Kunture obsidians. The norm selected is the composition of the primitive earth mantle as given by Sun and McDonough (1989).

| | Type A | | | | | | | | Type B | Type C | Type D |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Element (ppm) | MK 20/34-2 Melka Garba active bar | MK 20/36 Kella minor bed | MK 20/38 Kella old alluvium | MK 20/45 Awash Gorge minor bed | MK 2001/64 Balchit lava flow | MK 2001/63 Balchit lava flow | MK 20/46-3 Atebella old alluvium | MK 20/47-1 Atebella recent alluvium | MK 20/35-5 Melka Garba old alluvium | MK 20/37 Kella recent alluvium | MK 20/40 Simbiro old alluvium |
| Laboratory | So* | Gr | Gr | Gr | Gr | Gr | Gr | Gr | So | So | Gr |
| Co | | 0,84 | 0,76 | 0,82 | 0,87 | 0,84 | 0,86 | 0,89 | | | 4,49 |
| Cu | | 2,78 | 3,21 | 3,14 | 2,92 | 2,75 | 3,07 | 3,11 | | | 6,69 |
| Zn | | 48 | 37 | 38 | 38 | 36 | 40 | 40 | | | 108 |
| Ga | 18 | 18 | 16 | 17 | 18 | 18 | 17 | 18 | 19 | 19 | 23 |
| Rb | 193 | 182 | 167 | 170 | 179 | 180 | 174 | 185 | 196 | 136 | 139 |
| Sr | 63 | 69 | 65 | 67 | 70 | 71 | 67 | 73 | 61 | 20 | 20 |
| Y | 27 | 26 | 25 | 26 | 27 | 27 | 26 | 28 | 25 | 9 | 64 |
| Zr | 205 | 223 | 205 | 210 | 219 | 219 | 212 | 231 | 212 | 221 | 581 |
| Nb | 39 | 50 | 43 | 44 | 50 | 48 | 49 | 51 | 47 | 49 | 76 |
| Ba | 399 | 384 | 369 | 368 | 389 | 384 | 375 | 405 | 404 | 152 | 202 |
| La | 42 | 42 | 40 | 41 | 42 | 42 | 41 | 43 | 36 | 8 | 91 |
| Ce | 76 | 73 | 70 | 71 | 73 | 75 | 70 | 75 | 66 | 15 | 159 |
| Pr | 7,03 | 7,29 | 7,12 | 7,10 | 7,36 | 7,57 | 7,13 | 7,49 | 4,05 | 2,04 | |
| Nd | 21 | 22 | 22 | 21 | 22 | 23 | 22 | 24 | 13 | 7 | 70 |
| Sm | 3,85 | 3,85 | 3,91 | 3,76 | 3,94 | 4,07 | 3,89 | 4,19 | 2,58 | 2,00 | 12,69 |
| Eu | 0,44 | 0,45 | 0,43 | 0,43 | 0,45 | 0,45 | 0,45 | 0,43 | 0,12 | 0,02 | 1,01 |
| Gd | 3,25 | 3,73 | 3,46 | 3,69 | 3,82 | 3,81 | 3,72 | 3,81 | 2,31 | 2,14 | 11,21 |
| Tb | 0,62 | 0,66 | 0,67 | 0,64 | 0,66 | 0,66 | 0,63 | 0,65 | 0,43 | 0,41 | 1,90 |
| Dy | 4,15 | 4,18 | 4,23 | 4,14 | 4,17 | 4,19 | 4,03 | 4,35 | 2,87 | 2,86 | 11,08 |
| Ho | 0,88 | 0,88 | 0,90 | 0,89 | 0,93 | 0,94 | 0,91 | 0,94 | 0,61 | 0,62 | 2,35 |
| Er | 2,75 | 2,81 | 2,92 | 2,92 | 2,90 | 2,88 | 2,81 | 2,86 | 1,78 | 1,86 | 6,61 |
| Tm | 0,49 | | | | | | | | 0,32 | 0,34 | |
| Yb | 3,16 | 3,20 | 3,24 | 3,24 | 3,29 | 3,28 | 3,16 | 3,27 | 2,01 | 2,20 | 6,67 |
| Lu | 0,50 | 0,51 | 0,52 | 0,50 | 0,52 | 0,51 | 0,50 | 0,52 | 0,32 | 0,35 | 1,04 |
| Hf | 5,66 | 5,85 | 6,03 | 6,02 | 6,09 | 6,00 | 5,95 | 6,24 | 2,39 | 2,45 | 13,30 |
| Ta | 1,85 | | | | | | | | 3,56 | 1,90 | |
| Pb | 29 | | | | | | | | 27 | 23 | |
| Th | 18 | | 25 | 24 | 24 | 24 | 23 | 23 | 15 | 5,8 | 16 |
| U | 5,22 | | 5,17 | 5,24 | 5,25 | 5,06 | 5,29 | 5,08 | 4,80 | 4,66 | 3,33 |

Tab. 1. Trace element composition of Melka Kunture obsidians as determined by ICP-MS.

## Elemental composition

The elemental composition of eleven samples was determined by ICP-MS.

Eight samples were analysed at *Laboratoire de Géodynamique des Chaînes Alpines* (LGCA, Grenoble, France) and the remaining at *Southampton Oceanography Centre* (SOCFAC, Southampton, England), according to the procedure described by Barrat *et al.* (2000).

Twenty three and twenty six trace elements were determined respectively at SOCFAC and LGCA (Tab. 1). The analyses reveal four discrete compositional types. Obsidians of Melka Kunture-A type are represented by eight samples, seven of which were analysed in Grenoble. One observes the great compositional homogeneity of this group, and especially the significant agreement between analyses from the two laboratories (Fig. 9).

The other three samples, one analysed in Grenoble and two in Southampton, are representative of different geochemical types. Sample MK 20/40 (type D) differs from type A obsidians by its often greater trace elements content, especially Y, Zr, Hf and the rare earth elements, while sample MK 20/37 (type C) presents similar to lower trace elements content. Sample 20/35-5 (type B) behaviour is intermediate between that of obsidian of types C and D.

## Discussion and perspectives

The only identified source on the left bank of the Awash River is obsidian of type A (Balchit main lava outcrop). Thus, differences observed among the analysed samples concerning obsidians of types B and C may reflect minor variations among a single source during the emplacement of the lava or refer to unidentified sources upstream or on the left bank basin of the Awash River.

Obsidian of type D collected south of the Awash River in Simbiro Creek formations is a grey vitrous fluidal lava with a porphyric microstructure; quartz and feldspar crystals are oriented according to the fluidal structure. This material appears to be an ignimbrite facies which vitreous bedsole rapidly cooled in the contact with the substratum. We have identified several similar ignimbrites in this area.

The Balchit obsidian lava and its reworked debris are widely distributed in the paleoenvironment and form a major raw material source for prehistoric artefacts. In the future we may expect to identify more obsidian types in primary and secondary positions and including some flaked by hominids, especially in the southern part of the Melka Kunture area.

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