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KONSO-GARDULA RESEARCH PROJECT

Volume 1

Paleontological Collections: Background and Fossil Aves, Cercopithecidae, and Suidae

Edited by
Gen Suwa, Yonas Beyene, and Berhane Asfaw

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Paleontological Collections: Background and Fossil Aves, Cercopithecidae, and Suidae

Edited by

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Related Archival Materials: The KGA paleontological collection record plots (on file, available for viewing upon request)

Acknowledgements

The fossil specimens described in this volume are predominantly based on results of field research undertaken by the Konso-Gardula Paleoanthropological Research Project (KGA Project), co-directed by Yonas Beyene and Gen Suwa, under permission of the government of Ethiopia. We thank the Authority for Research and Conservation of Cultural Heritage (A.R.C.C.H., formerly the C.R.C.C.H.) of the Ministry of Culture and Tourism of Ethiopia for the continued support to the project over the years. All fossils and artifacts are currently stored in the laboratory facilities of the A.R.C.C.H., Addis Ababa. Berhane Asfaw initiated the Paleoanthropological Inventory of Ethiopia in 1988, which led to the 1991 discovery of the fossiliferous and artifact-rich deposits of the Konso area. A limited number of fossils were collected by the Inventory Project at Konso, which were integrated with the larger KGA Project collection.

We thank the Ethiopian government and its many individuals involved in supporting and promoting paleoanthropological research in Ethiopia, and in particular enabling the field and laboratory research of the KGA Project. We thank the Southern Nations, Nationalities, and People's Regional State (S.N.N.P.R.S.), the Culture and Tourism Bureau of the S.N.N.P.R.S., and the Konso administrative district for their support and facilitation to the research.

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CHAPTER 1

Introduction

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The Konso-Gardula (KGA) paleoanthropological research area was first discovered in fall 1991, by the field project led by one of us (B.A.) the Paleoanthropological Inventory of Ethiopia (Asfaw et al., 1992). The Inventory project led to the unexpected realization that sediments exposed in the Karat (or Konso) town area were rich in Early Pleistocene artifacts and vertebrate fossils. A brief summary of the events at Konso-Gardula that led to its discovery will be provided elsewhere (Beyene et al., in prep). The research area was initially named after the two administrative districts, Konso and Gardula (now the Derashie administrative district) where the sediments crop out. Thereafter, administrative boundaries changed so that the entire research area lies within the Konso district. Therefore, for brevity, we alternatively call the research area and the project the Konso paleoanthropological research area or project.

Mammalian evolution in eastern Africa between the time period of one and two million years ago has been best documented by fossils recovered from Olduvai Gorge, Tanzania (e.g., Leakey, 1965; Gentry and Gentry, 1978a, b; Harris and White, 1979; Potts,1988) and the Turkana Basin, Kenya and Ethiopia (e.g., Coppens et al., 1976; Harris and White, 1979; Harris, 1983, 1991; Coppens and Howell, 1985; Beden, 1987; Eck et al., 1987; Harris et al., 1988; Geraads, 1995; Geraads and Coppens, 1995; Behrensmeyer et al., 1997; Jablonski and Leakey, 2008). In Ethiopia, renewed work at the lower Omo Valley (Boisserie et al., 2008, 2010) have started to produce important new insights into this time period. Comparatively smaller assemblages from this time interval have also been described from various regions of Tanzania (Geraads, 1987; Frost et al., 2012), Ethiopia and Djibouti (Geraads, 1979; de Bonis et al., 1988), and Kenya (Gentry and Gentry, 1978a, b; Harris and White, 1979; Ditchfield et al., 1999), but the predominance of the Olduvai Gorge and Turkana Basin assemblages nevertheless remains.

The KGA research area is located at the southern extremity of the Ganjuli Graben, south of Lake Chamo, approximately 180 km northeast of the fossiliferous Plio-Pleistocene deposits of the northern Turkana Basin. The Ganjuli Graben occupies the southwestern extremity of the Main Ethiopian Rift, and is offset to the east from the Stephanie Rift, the latter a northern extension of the Kenyan Gregory Rift. The Early Pleistocene sediments of the Konso Formation occur between 1,100 and 1,500 meters altitude in the headwaters of the Gato/Iyanda drainage system, a tributary of the Segen River. This region is separated from the Stephanie Rift and the Turkana Basin by the Konso mountainous terrain of approximately 1,600 to 2,100 m altitude.

At Konso, we systematically collected over 8,000 taxonomically identifiable mammalian fossil specimens, which provide an additional dimension to the understanding of mammalian evolution in eastern Africa of an otherwise Olduvai and Turkana dominated outlook. We have previously published an overview of aspects of the Konso Formation Early Pleistocene fauna (Suwa et al., 2003). Despite its proximity to the Turkana Basin, some taxonomic groups exhibit strikingly different species representations. In some of such species/species sets, strong resemblances with the Olduvai fauna are seen, while, in others, affinities with the Afar region fauna are inferred (Suwa et al., 2003). At Konso, considerable species turnover are seen between 1.9 Ma and 1.4 Ma, and some of such patterns appear distinct from temporal changes seen in the Turkana Basin fauna. Yet, at Konso, other lineages show continuity through time, broadly in common with, but not necessarily identical to, what is known at the Turkana Basin. Careful evaluations of regional patterns of evolutionary trajectories may shed light on a complex intra- and inter-regional matrix of faunal change and its environmental circumstances. Clearly, much more insight remains to be gained from key fauna assemblages such as those from Konso and elsewhere.

This volume is the first of several, by means of which we aim to systematically present materials collected and analyzed by the KGA project, including paleontological, archeological and geological evidence. Regarding the paleontological materials, the purpose is to provide the basic descriptions, taxonomic assessments, and chronostratigraphic placements of the fossils collected from the Konso Formation between 1991 and 2010, which total over 8000 specimens. Most of the fossils were systematically collected between 1993 and 2000, and in 2010 at a newly recognized collection area. A smaller number of fossils were collected in 1991 by the Inventory Project.

In Chapter 2, we summarize the collection and documentation methodologies, including the cataloguing system that we adopted. In Chapter 3, we summarize and provide the stratigraphic and chronological background of the collected fossils. Chapters 4 through 6 are systematic presentations of the fossils attributed to Aves, Cercopithecidae, and Suidae. The other taxonomic groups will be presented in a similar format in due course, as the descriptive and curatorial work sufficiently advances.

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CHAPTER 2

The Konso Formation Paleontological Assemblages: Collecting and Documentation Methodologies

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2.1 COLLECTING PROCEDURES

The Konso paleoanthropological research area is divided into 21 collecting localities (Figs. 2.1 and 2.2). These were designated and defined to broadly coincide with accessible sedimentary outcrop patches of circa one or more kilometers in diameter. Locality boundaries are defined predominantly by ridge tops, valley floors, or uplifted basement, and occasionally by visible faults that bring into contact non-overlapping stratigraphic intervals.

Most of the paleontological specimens were recovered by systematic surface survey. A limited number of fossils were obtained by sieving operations related with hominid (the human side of the *Pan*-human phylogenetic split) discoveries. When systematic paleontological surveys were not conducted, few fossils were selectively collected when specimens of significance were encountered during geological, paleoenvironmental, and/or archeological survey/sampling. Because of limited storage capacity available at the National Museum of Ethiopia at the time of the field work, we systematically collected the mammalian fossils according to the following criteria.

(1) All fossils recognized in the field as cercopithecid, hominid, or carnivoran.

(2) All bovid, suid, giraffid, equid, rhinocerotid, and chalicotheriid partial crania, horn cores, measurable dentognathic remains, and postcranial remains with preserved articular ends. We restricted isolated dental remains to measurable teeth in the more abundant taxa, but systematically included suid M3s with only approximately half of their crowns preserved because of their utility in taxonomic assessments. Horn cores were usually confined to those that preserve a portion of the base.

(3) All elephantid third molars (about one-third or more complete) with preserved mesial or distal ends.

(4) Hippopotamid fossils were not purposefully collected in the 1993 to 2002 field work, although a small number of specimens were collected as possible suiform, and later identified as hippopotamid (mostly phalanges and incisors). A small number of taxonomically diagnostic hippopotamid fossils were collected in 2010, in order to document the most abundantly represented taxa.

(5) All micromammalian fossils observed on the surface.

(6) Reptilian and avian fossils were comparatively rare, aside from the fragmentary crocodile

and turtle fossils which were common at some of the localities. All avian fossils and some few relatively well-preserved reptilian postcranial elements were collected as noticed in the field.

Surface prospecting was systematically conducted so that all specimens were found and recovered within sight of at least one scientist who logged both geographic and estimated stratigraphic positions of each fossil. The location of each find was recorded on site using aerial photographs enlarged to approximately 1:5000 scale, usually enabling plot accuracy of circa 10 to several tens of meters. Plot resolution and accuracy by this method are better than the general GPS readings that were available to us in the early to mid-1990s. Because of the limited vertical stratigraphic extent of most outcrops, this enabled a reasonably accurate spatial and stratigraphic provenience record for paleontological analyses. The locations of hominid discoveries were revisited in August 2000, and recorded by differential GPS. We note that when these dGPS coordinates are plotted onto Google Earth imagery they show the latter to be offset by ~10 meters (as of August 2013).

Systematic surface collecting was undertaken in short field seasons of 1993 through 1997 and 2000. The number of collected specimens (as of the August 2013 catalogue) by locality and year is summarized in Table 2.1. Specimen by specimen location plots of fossils collected at the major localities between 1993 and 2010 were compiled as archival materials (available for viewing upon request). Individual specimen plots were not made at KGA4, where collection areas were designated and recorded together with the stratigraphic level. In 2010, a newly recognized exposure east of the main KGA4 outcrops was systematically collected.

Table 2.1. Summary of paleontological specimens collected from the Konso Formation

	1991	1993	1994	1995	1996	1997	1998	1999	2000	2002	2003	2010	TOTAL
KGA1													0
KGA2										1			1
KGA3	4												4
KGA4	26	64	961	599	587	249	1		28	6		83	2604
KGA5	1					73							74
KGA6				34	8					2	1		45
KGA7	9	1	144	73	59	92							378
KGA8	5		265	71	102	2			1				446
KGA9		1											1
KGA10	19	471	898	212	1087	3	5	1	10	1	1	9	2717
KGA11	2		57		1	192			20				272
KGA12	3	6	551	186	351	2			3				1102
KGA13					1								1
KGA14		1		3					1				5
KGA15													0
KGA16						25							25
KGA17				41		38							79
KGA18						16							16
KGA19						10		3	148				161
KGA20									109				109
KGA21						82		1	32	21			136
TOTAL	69	544	2876	1219	2196	784	6	5	352	31	2	92	8176

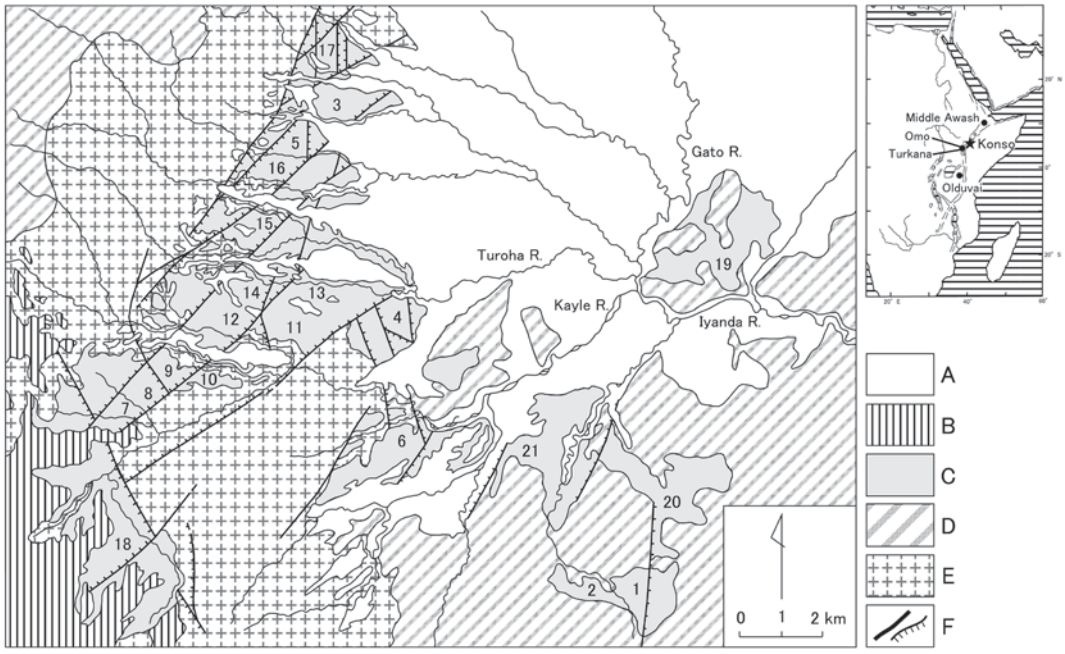

Fig. 2.1. Geologic map and localities of the Konso Formation. Numbers in the map refer to collecting localities named in sequence from KGA1 to KGA21. A, Middle Pleistocene to Holocene fluvial deposits; B, Early to Middle Pleistocene erosional surface deposits; C, Early Pleistocene Konso Formation; D, Eocene to Miocene mafic lavas; E, Precambrian crystalline basement rocks; F, faults with downthrown side shown by ticks.

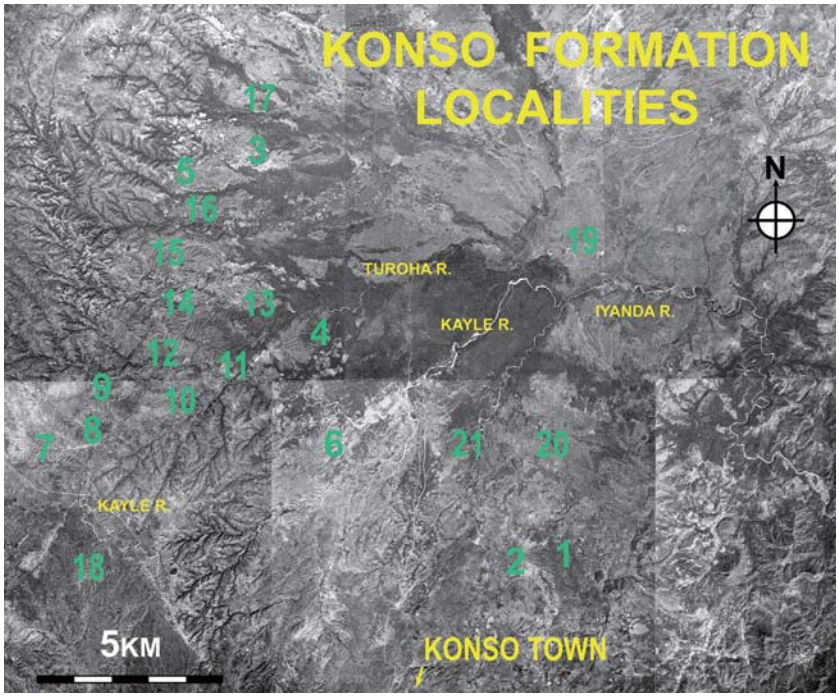

Fig. 2.2. The Konso Formation localities designated for survey and collecting.

2.2 CATALOGUE PROTOCOL AND METHODS

The following cataloguing protocols and recording fields were applied.

1) Collection area (KGA locality area #).

2) Specimen number and suffix/accessory number.

For the KGA paleontological collection, each fossil piece or set of pieces considered to belong to the same individual were given a number (usually in the field), which in combination with the KGA locality number is the specimen number in the format: KGA4-1 or KGA10-101. These are the "specimen numbers" used in all subsequent studies and catalogues, but with the following adjustments when necessary. When the initial set of fossils (given a unique specimen number) is recognized to comprise more than one individual, these are subdivided into distinct specimen numbers using an alphabetical suffix (such as KGA12-1a, KGA12-1b, KGA12-1c). Conversely, when fossils individually collected and initially given different numbers were determined in the laboratory to comprise the same individual, the latter number becomes the accessory number in the format such as KGA10-17/2799.

3) Element code: C, cranial; D, dental; P, postcranial.

4) Side: L, left: R, right.

5) Element descriptions.

Body parts are logged using the abbreviation codes of Table 2.2. Specimens listed as "frag" include fragmentary specimens, such as bovid horn cores lacking bases and bovid and equid teeth in which either mesiodistal or buccolingual dimensions are not measurable (or unable to reasonably estimate). Suid M3s in which mesiodistal lengths are not measurable are listed as "incomplete", "partial" or "frag". Category "incomplete" includes M3s of *Kolpochoerus limnetes, K. olduvaiensis* and *K. limnetes/olduvaiensis* with 3 pillar pairs or more, those of *Metridiochoerus compactus* with circa 2/3 crown or more, and those of *M. hopwoodi* and *M. modestus* with 4 pillar pairs. Category "partial" includes M3s of *K.* cf. *majus, K. limnetes, K. olduvaiensis* and *K. limnetes/olduvaiensis* with 2 pillar pairs, and those of *M. hopwoodi, M. modestus* and *M. compactus* with circa 1/2 crown. Category "frag" includes suid M3s more fragmentary than those of the "partial" category.

5) Taxonomic designations.

6) Discovery date.

7) Stratigraphic code and positions.

The stratigraphic level and location descriptions within each collecting locality were documented, and codes were given to designate the major collecting horizons. Further explanations are given in Chapter 3.

8) Level.

This refers to stratigraphic levels in reference to tuff levels of the composite Konso Formation stratigraphy. A fuller description is detailed in Chapter 3.

Table 2.2. Body part nomenclature and codes

Element code	Element
MAN	mandibular fragments: preserved tooth crowns are listed in parenthesis
MAX	maxillary fragments: preserved tooth crowns are listed in paraenthesis
VER	vertebrae
ATL	atlas
COS	costae
SCA	scapula
FEM	femur
HUM	humerus
TIB	tibia
FIB	fibula
RAD	radius
ULN	ulna
TAR	tarsus
CAR	carpus
TBT	tibiotarsus
TMT	tarsometatarsus
CAL	calcaneum
AST	astragalus
NAV	navicular
CUB	cuboid
NVC	naviculocuboid
CUN	cuneiform
SCP	scaphoid
LUN	lunate
TRI	triquetrum
UNC	unicform
MAG	magnum
PIS	pisiform
SES	sesamoid
MTT	metatarsus
MTC	metacarpus
MTP	metapodial
PHX	phalanx: prox, int, dist refer to proximal, intermediate and distal phalanges; ray designations are in roman numerals

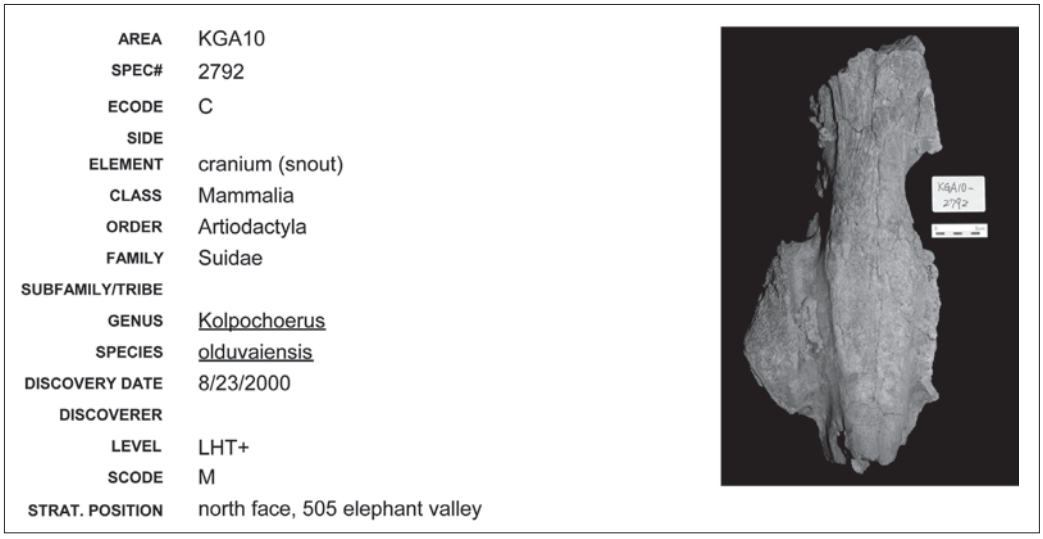

Fig. 2.3. Konso paleontology catalogue entry example.

CHAPTER 3

Stratigraphic and Chronologic Context of the Konso Formation Paleontological Collection

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The Early Pleistocene (definition of Pleistocene here follows Gibbard et al., 2010) sediments exposed in the Ganjuli Graben, the southernmost part of the Main Ethiopian Rift northeast of Konso, were formally defined as the Konso Formation by Nagaoka et al. (2005). The chronostratigraphic framework of the Konso Formation was presented in some detail in Katoh et al. (2000) and Nagaoka et al. (2005), focusing on localities KGA4 and KGA6 to KGA14. Summary results of the tephrostratigraphy of KGA18 through KGA21, the geographically more peripheral localities, were added by Beyene et al. (2013). The localities KGA1, KGA2, KGA3, KGA5, and KGA15 to KGA17 have not yet been described. The KGA1 and KGA2 Konso Formation sediments are broadly correlative to those of the KGA18 and KGA20 sections. Sediments exposed at localities KGA3, KGA5, and KGA15 to KGA17 are broadly comparable in age to KGA12 through KGA14 and the middle/upper sequence of KGA11. A fuller presentation of the entire Konso Formation geology is under preparation.

The Konso Formation represents unconsolidated sediments of predominantly lacustrine and lake-margin fluvial lithofacies that accumulated at the southern extremity of a small subsiding sedimentary basin. A lacustrine depositional environment is thought to have intermittently prevailed in the area, with the maximum paleolake expansion of up to 2 km east–west and 8 km north–south at about <~1.3 Ma to ~1.4 Ma (Nagaoka et al., 2005). The uppermost sediments of the Konso Formation at ~0.85 Ma age are exposed several kilometers farther south, suggesting that there was either additional lake expansion or a shift of the paleolake location after 1.0 Ma. The northeastern extent of this paleolake cannot be determined from available surface exposures. However, the topography of the Ganjuli Graben and the lack of known contemporary sediments in the Lake Chamo Basin suggest that the Konso paleolake was confined to the southern extremity of the graben, rather than being part of a greater paleolake Chamo. The relative rarity of fossil fish remains in much of the Konso Formation supports this interpretation. Fossils and lithic artifacts occur mainly in the fluvial sediments of small river systems, mostly representing lake-margin floodplain and alluvial fan settings. These river systems were perhaps equivalent in development to the present day tributaries of the Gato/Iyanda Rivers.

In the Suwa et al. (2003) overview of the Konso Formation fauna, the fossil assemblages were

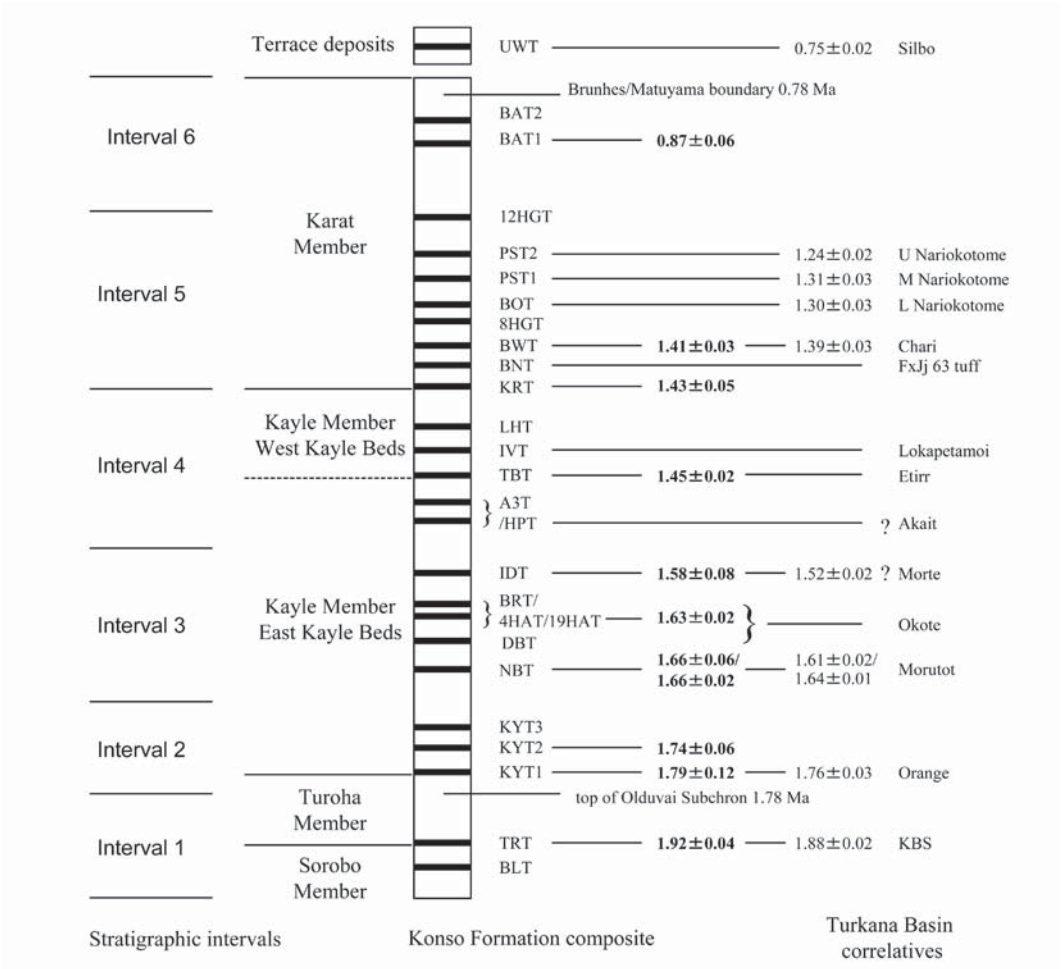

Fig. 3.1. Konso Formation member designations and schematic stratigraphic column.See Beyene et al. (2013) for details of the dating and chronology.

reported in reference to six time-successive stratigraphic intervals that do not overlap in time. This remains a useful and valid reference of comparison, and an updated version is provided here. Fig. 3.1 shows the six stratigraphic intervals in relation to a schematic stratigraphic column depicting the Konso Formation member divisions/subdivisions and stratigraphic placements of 27 major Konso tuffs. The Hard Gray Tuff (HGT) was first described as one of the uppermost tuffs of the Konso Formation (Katoh et al., 2000). Here, we distinguish two different tuffs named the KGA8 Hard Gray Tuff (8HGT) and KGA12 Hard Gray Tuff (12HGT) in ascending stratigraphic order. Table 3.1 lists the tuffs, abbreviations, and their locality occurrences.

We have previously reported radioisotopic ages of 10 marker tuffs and their relationship with the two major paleomagnetic boundaries, the Brunhes/Matuyama (B/M) boundary and

Table 3.1. Key tephra of the Konso Formation and abbreviations

Konso Formation tuffs	Abbreviation	Localities
Upper White Tuff	UWT	KGA20
Baraisa Tuff-2	BAT2	KGA1, KGA2, ?KGA18, KGA20
Baraisa Tuff-1	BAT1	KGA1, KGA2, KGA18, KGA20
KGA12 Hard Gray Tuff	12HGT	KGA9, KGA12, KGA14, KGA15
Piso Tuff-2	PST2	KGA12
Piso Tuff-1	PST1	KGA3, KGA7
Boleshe Tuff	BOT	KGA5, KGA7
KGA8 Hard Gray Tuff	8HGT	KGA5, KGA8
Bright White Tuff	BWT	KGA3, KGA5, KGA6, KGA7, KGA8, KGA9, KGA11, KGA12, KGA13, KGA14, KGA18
Bench Tuff	BNT	KGA5, KGA7, KGA8, KGA9, KGA12, KGA13, KGA14, KGA15, KGA16, KGA17
Karat Tuff	KRT	KGA3, KGA5, KGA7, KGA8, KGA9, KGA12, KGA13, KGA14, KGA15, KGA16, KGA17
Lehayte Tuff	LHT	KGA9, KGA10, KGA11
Ivory Tuff	IVT	KGA8, KGA10, KGA11
Trail Bottom Tuff	TBT	KGA4, KGA5, KGA6, KGA8, KGA9, KGA11, KGA13, KGA14, KGA16, KGA19
A3 Tuff	A3T	KGA4, KGA19
Hope Tuff	HPT	KGA5, KGA13, KGA14, KGA19
Iyanda Tuff	IDT	KGA19
Konso Brown Tuff	BRT	KGA19, KGA21
KGA4 Handaxe Tuff	4HAT	KGA4
KGA19 Handaxe Tuff	19HAT	KGA19
Doublet Tuff	DBT	KGA19
KGA19 Bench Tuff	NBT	KGA19
Kayle Tuff-3	KYT3	KGA6
Kayle Tuff-2	KYT2	KGA6, KGA19
Kayle Tuff-1	KYT1	KGA6, KGA19
Turoha Tuff	TRT	KGA4, KGA11
Blue Tuff	BLT	KGA4

Table 3.2. Major collection localities and horizon nomenclature

Locality	Code	Horizon designation	Stratigraphic relationship to tuffs
KGA4	M	Main level	above BLT to ~TRT
	HA	Handaxe block	~4HAT
	E	Eastern block	~A3T to ~TBT
KGA5	M	Main level	~BWT to ~8HGT
	L	Lower level	~TBT to KRT
KGA6	M	Main level	~KYT1/2
	L	Lower level	>10 m below KYT1
KGA7/8	U	Upper level	above BWT to ~8HGT or ~BOT or ~PST1
	M	Main level	mostly ~BNT to ~BWT
	L	Lower level	between IVT and KRT
KGA10	U	Upper level	no tuffs exposed, but sub-KRT equivalent
	M	Main level	sub-LHT to above LHT (mixture from U level possible at places)
	L	Lower level	sub-IVT to cf TBT equivalent levels (TBT not exposed at KGA10)
KGA11	U	Upper level	~BWT
	M	Main level	sub-TBT to ~LHT
	L	Lower level	~TRT
KGA12	M	Main level	~BWT to mostly just below 12HGT
	ML	Main lower level	~BNT (mixture from M level possible at places)
	L	Lower level	sub-KRT (mixture from ML level possible at places)
KGA16	U	Upper level	just above BNT
	M	Main level	sub-TBT to KRT
KGA17	M	Main level	circum BNT
KGA18	M	Main level	~BAT1 to ~BAT2 equivalent
KGA19	M	Main level	19 west south face, ~DBT to sub-IDT
	ML	Main lower level	19 west northwestern block, circum NBT
	L	Lower level	19 east, sub-KYT1
KGA 20	U	Upper level	between BAT1 and BAT2
	L	Lower level	just below BAT1
KGA 21	M	Main level	sub-BRT

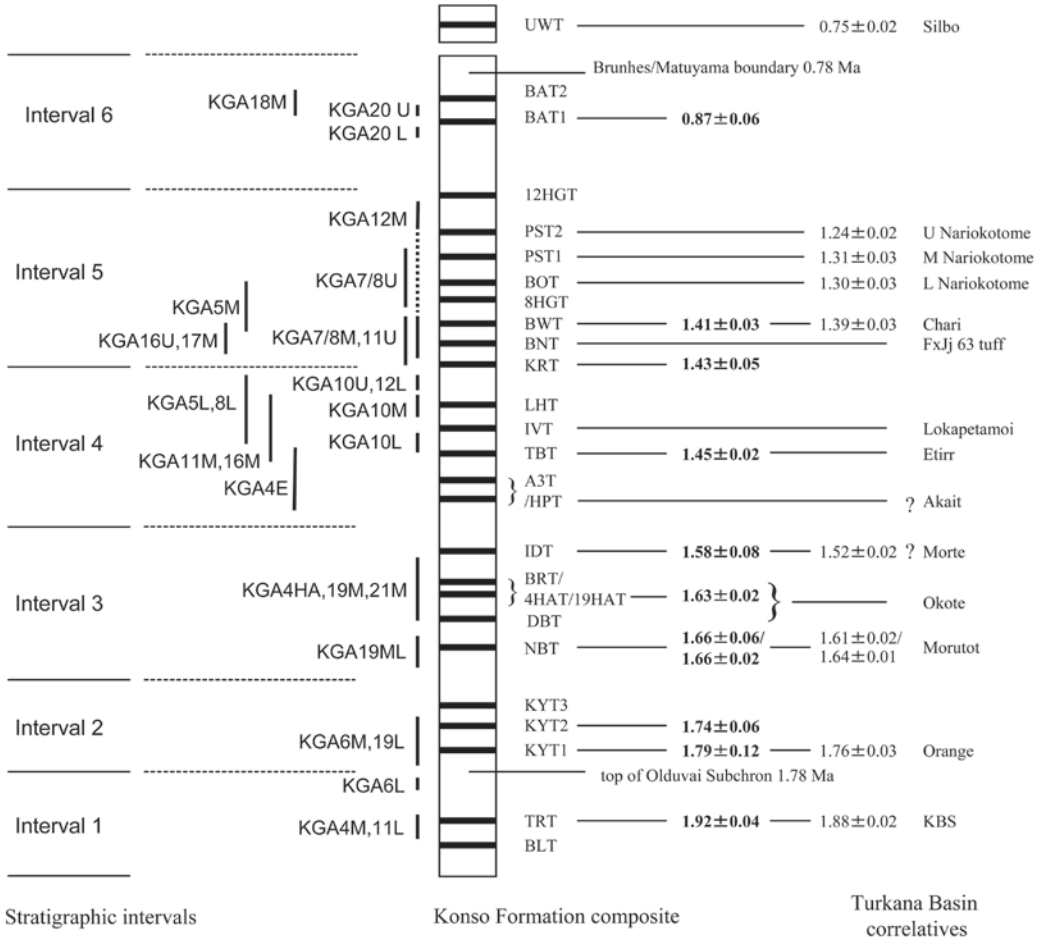

Fig. 3.2. Schematic stratigraphic column of the Konso Formation, stratigraphic intervals, and fossil collection levels of the main localities. See Beyene et al. (2013) for details of the dating and chronology.

the top of the Olduvai Subchron (Katoh et al., 2000; Beyene et al., 2013). Correlation of tuffs between the Konso Formation and the Early Pleistocene deposits of the Omo-Turkana Basin provide additional age constraints (Fig. 3.1, detailed in WoldeGabriel et al., 2005; Beyene et al., 2013). Fig. 3.2 shows the KGA localities and fossil collection horizons in relation to the composite chronostratigraphic column of the Konso Formation. Table 3.2 summarizes the collecting horizons of the major KGA localities. Simplified stratigraphic columns and their locations are shown in the Figs. 3.3 to 3.10.

Only few specimens were found *in situ* in the sediments, and the vast majority of collected fossils were found eroded out from the sediments. In certain specific finds, such as with the hominid specimens KGA10-1 and KGA10-525 (Suwa et al., 1997), the sedimentary section

at the find spot was scrutinized, multiple fossiliferous horizons identified, and the most likely horizon of origin determined from a combination of adhering matrix and inferred patterns of post-erosion dispersion. From such evaluations and other similar assessments of local stratigraphic sections and erosional topography, each of the coded collecting horizons was considered broadly coherent within the limits shown in Fig. 3.2 and Table 3.2. These coded collecting horizons each represent an aggregate of fossils from multiple fossiliferous horizons, but the vast majority of fossils are considered to have come from the assigned stratigraphic intervals. However, some degree of mixture cannot be precluded, mostly in places where a highly fossiliferous horizon occurs up-stratigraphy in considerable proximity, as at some areas of KGA10 and KGA12. These instances are noted in Table 3.2.

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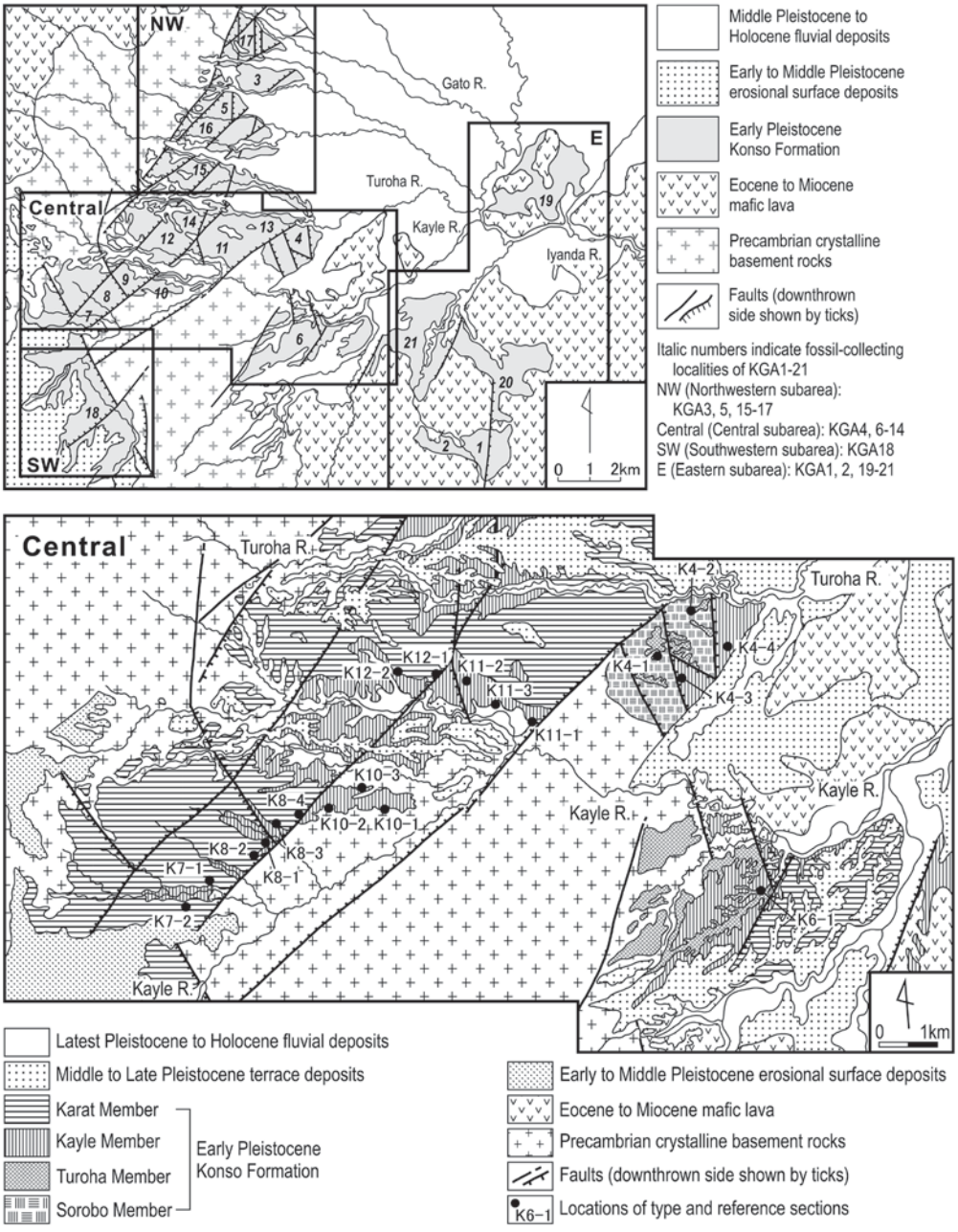

Fig. 3.3. Konso paleontological collecting localities and locations of stratigraphic columns. Top panel: circumscribed areas enlarged in bottom panel and in Fig. 3.4. Bottom panel: approximate locations of stratigraphic columns of the Central area localities, KGA4, KGA6, KGA7, KGA8, KGA10, KGA11 and KGA12 (Figs. 3.5 to 3.8).

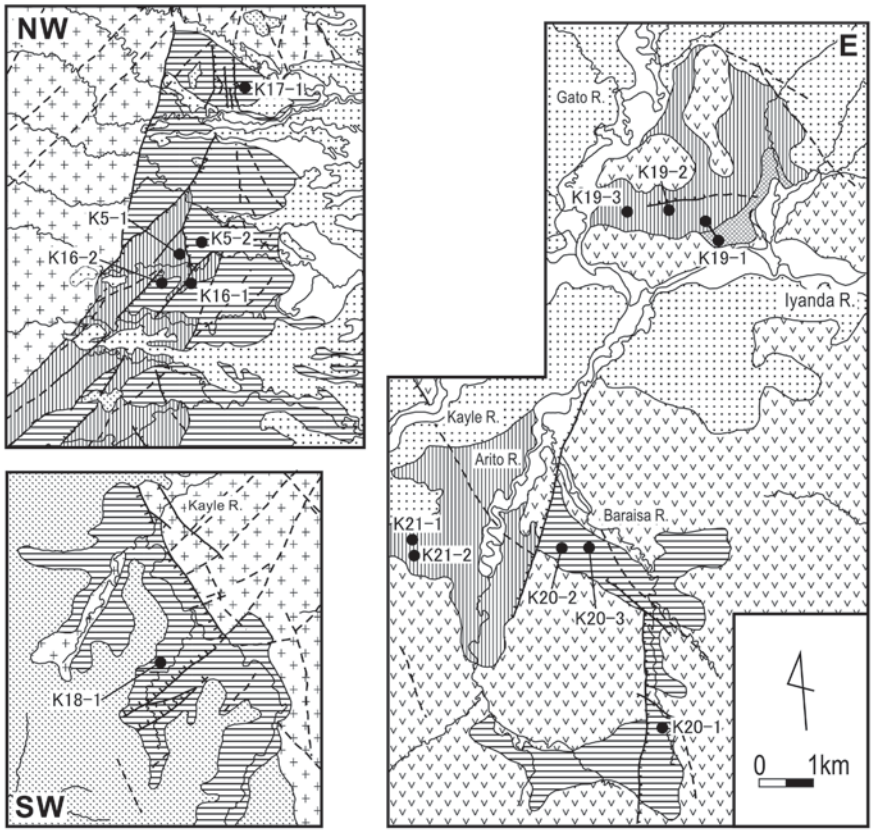

Fig. 3.4. Locations of stratigraphic columns. Top left panel: Northwestern area localities, KGA5, KGA16 and KGA17 (Fig. 3.9). Bottom left panel: Southwestern area locality, KGA18 (Fig. 3.10). Right panel: Eastern area main localities, KGA19, KGA20 and KGA21 (Figs. 3.6, 3.10). See Fig. 3.3 for legends.

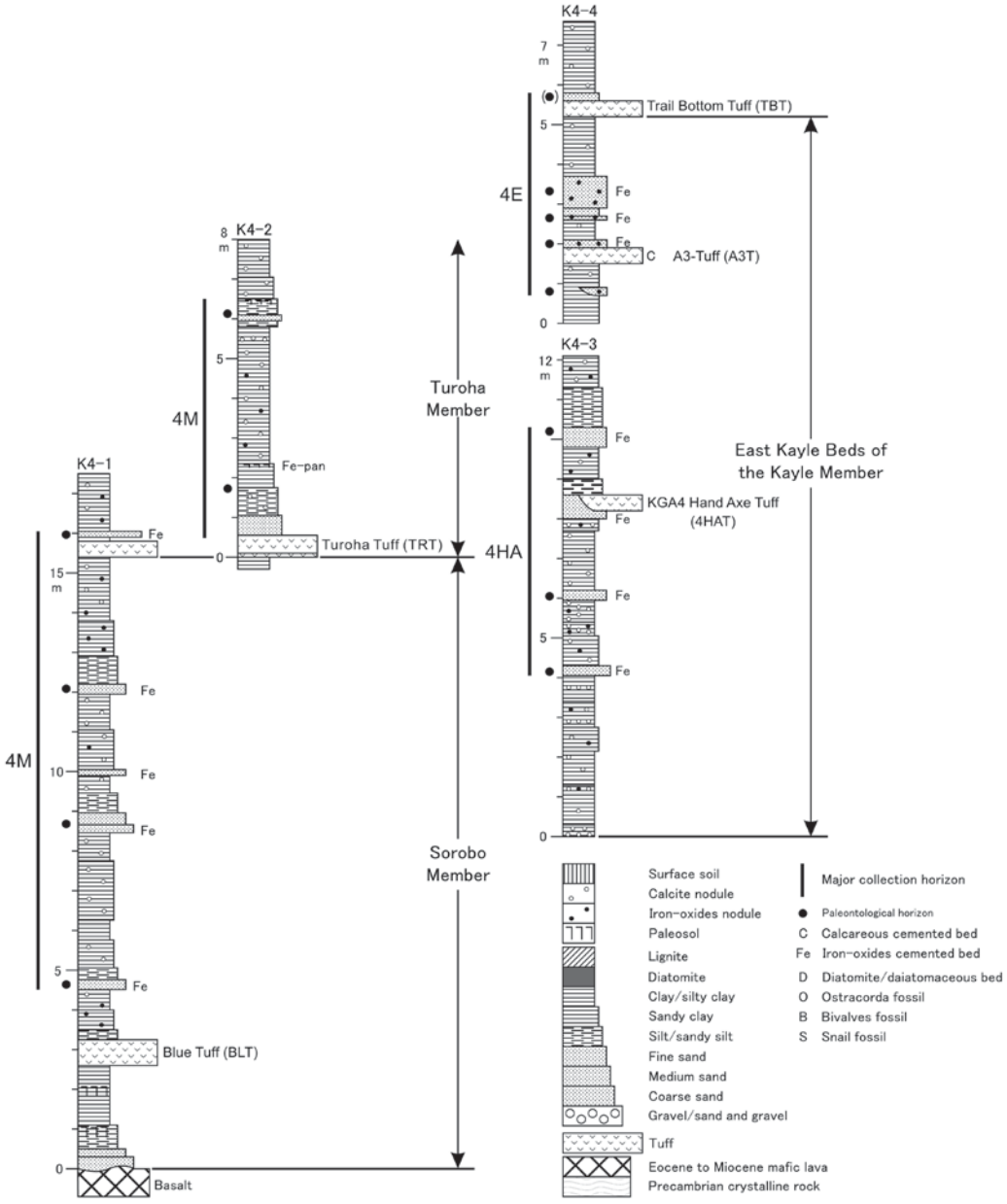

Fig. 3.5. KGA4 schematic stratigraphic columns and collected horizons.

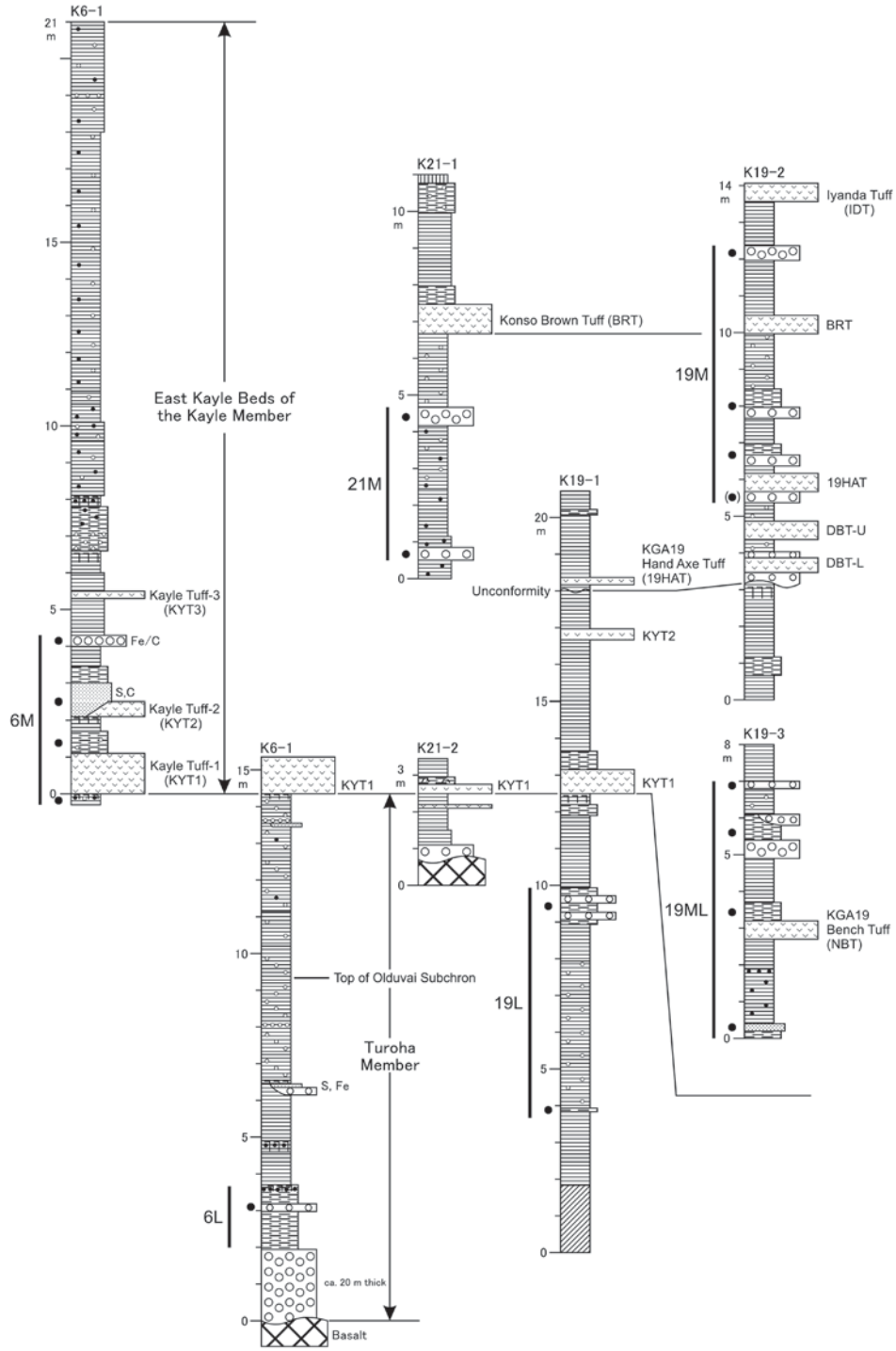

Fig. 3.6. KGA6, KGA19 and KGA21 schematic stratigraphic columns and collected horizons.

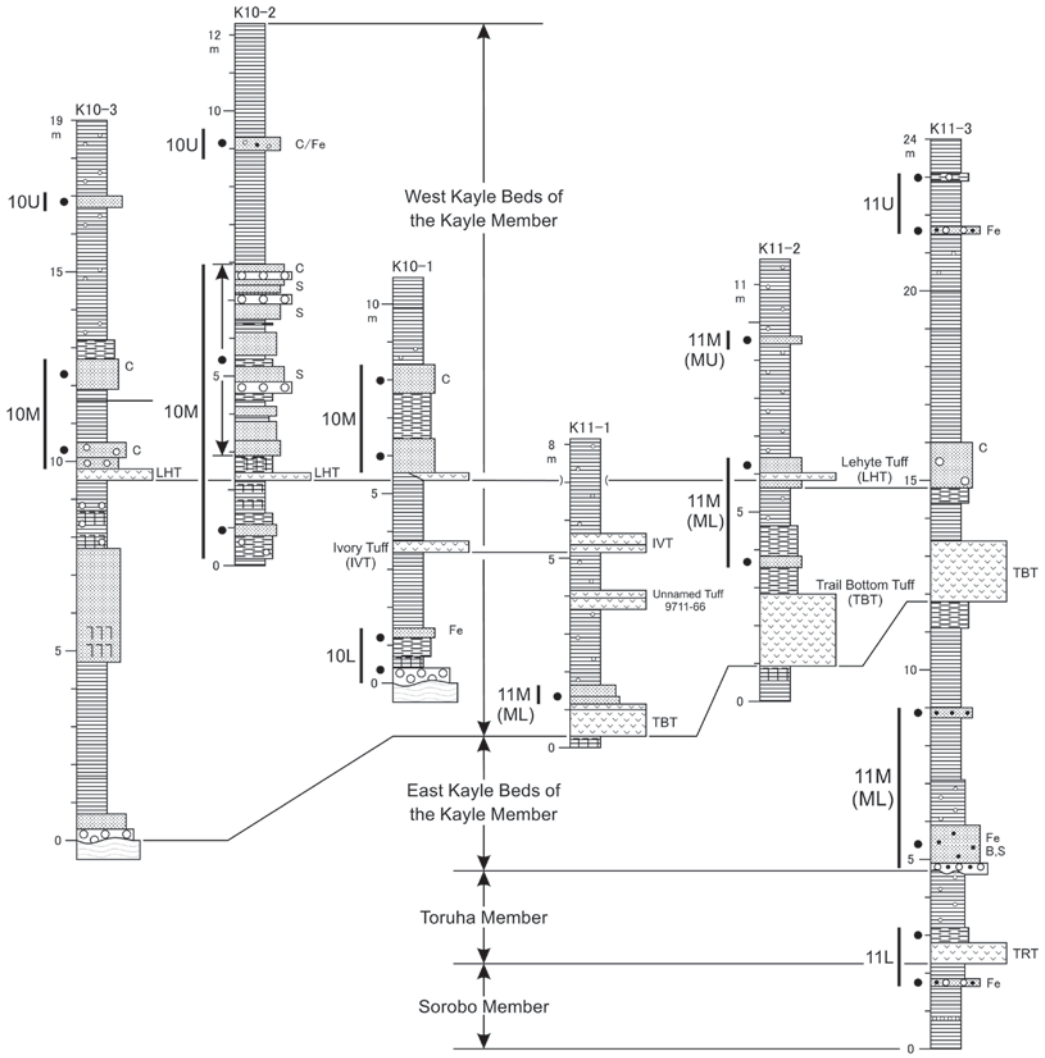

Fig. 3.7. KGA10 and KGA11 schematic stratigraphic columns and collected horizons.

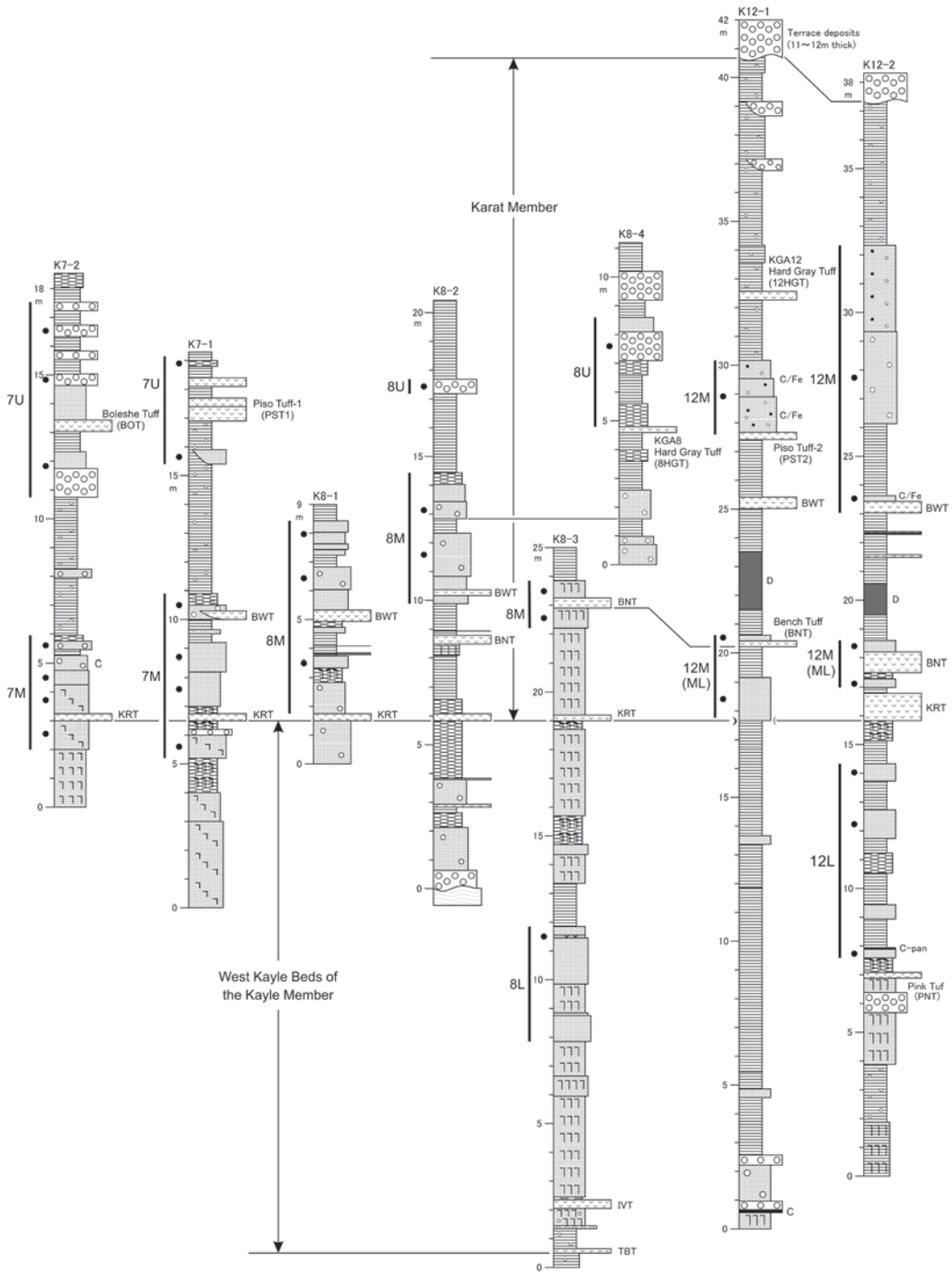

Fig. 3.8. KGA7, KGA8 and KGA12 schematic stratigraphic columns and collected horizons.

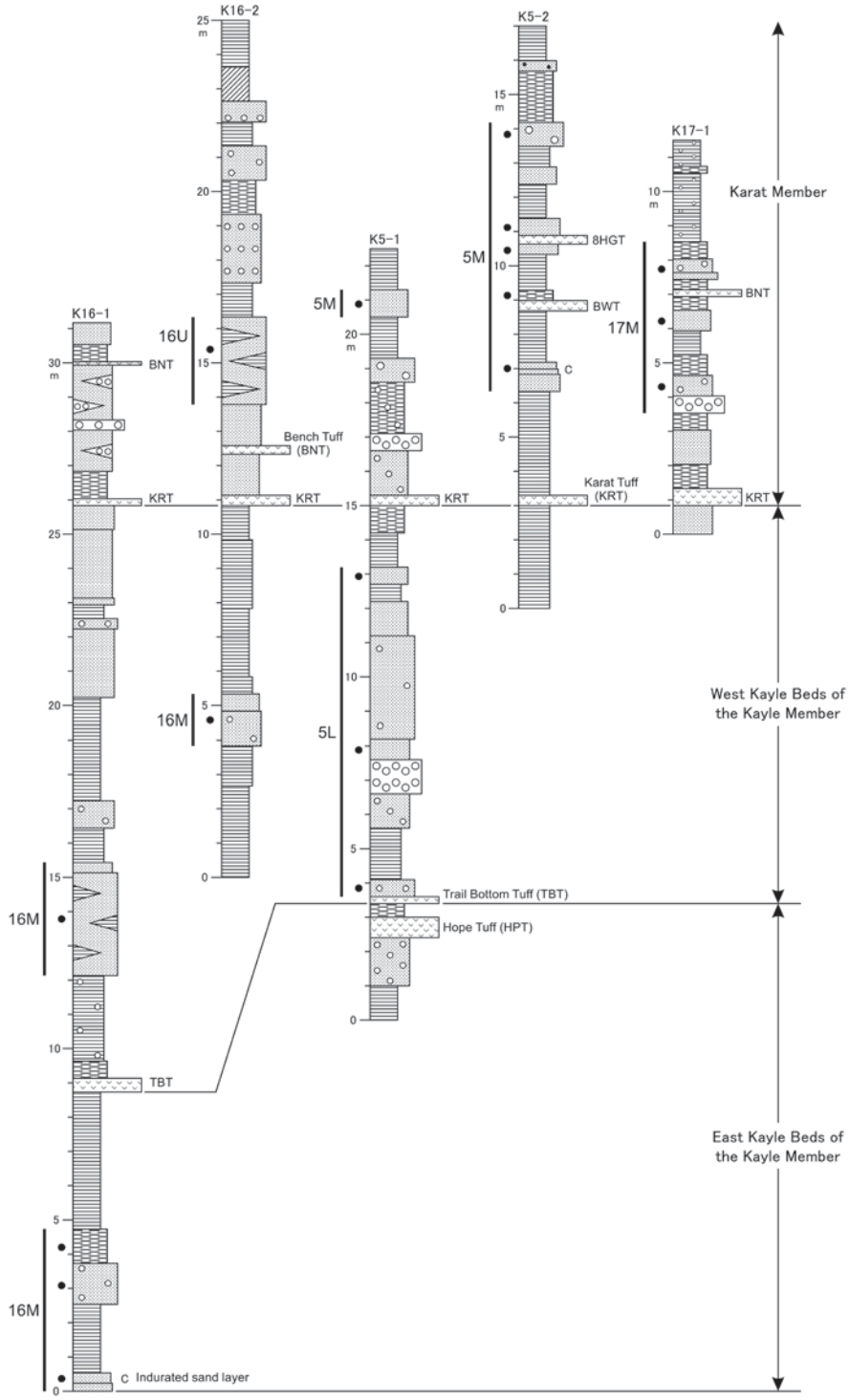

Fig. 3.9. KGA5, KGA16 and KGA17 schematic stratigraphic columns and collected horizons.

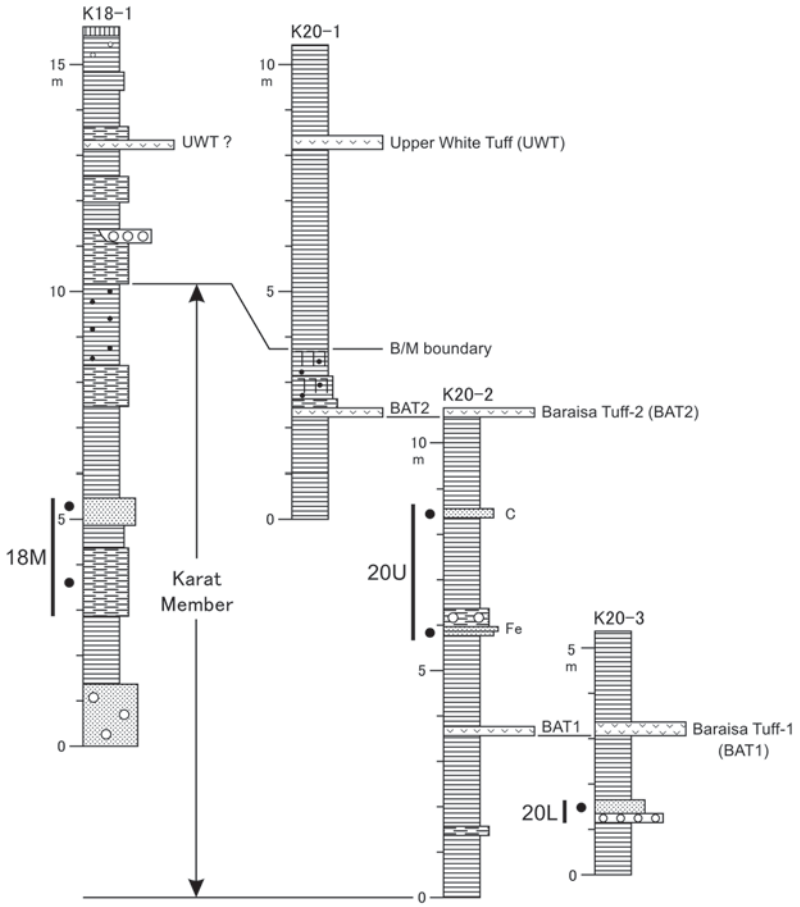

Fig. 3.10. KGA18 and KGA20 schematic stratigraphic columns and collected horizons.