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Compilation of geochronological data for Cenozoic volcanic activity on the African plate and for selected Northern African sedimentary basins

Geological Survey of Norway
Postboks 6315 Sluppen
NO-7491 Trondheim, Norway
Tel.: 47 73 90 40 00
Telefax 47 73 92 16 20

REPORT

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Compilation of geochronological data for Cenozoic volcanic activity on the African plate and for selected Northern African sedimentary basins

Authors:
Bart W.H. Hendriks

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NGU, Statoil

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Summary:
A compilation of published isotope geochronological data for Cenozoic volcanic / magmatic activity on the African plate and for part of the adjacent Antarctic plate was created within The African Plate project (TAP; collaboration between NGU and Statoil). This compilation covers the continental as well as the oceanic part of the African plate. Areas with documented recent or historic volcanic or magmatic activity are also included. In addition, geochronological data for selected Northern African sedimentary basins (Tadouenni, Kufra, Murzuq, Illizi, Sirte) were included. The vast majority of these data are from surface outcrops in areas immediately adjacent to these basins, rather than from the basins themselves (where few published isotope ages exist). Published data included in this database are obtained from the following isotope geochronological methods: Ar/Ar, K/Ar, Re/Os, Rb/Sr, Sm/Nd, Lu/Hf, FT, U/Pb, Pb/Pb and U-Th/Pb. Details on laboratory methodologies, age statistics, etc., are included as much as possible. For the Cenozoic volcanics a subdivision into alkaline and non-alkaline rocks was made following a broad definition by Woolley (2001) as well as a much more narrow definition by Kevin C. Burke (including only nephelinite, nepheline syenite, phonolite and sövite).

Keywords: geochronology	Volcanic rocks	Africa
Cenozoic	sedimentary basin	isotope
alkaline		

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Electronic supplement; TAPgeochronARC.accdb
(Microsoft Access Database; single table)

1. INTRODUCTION

The database of isotope geochronological data described here consists of two parts: (1) Cenozoic volcanic and magmatic activity on the entire African plate as well as on part of the adjacent Antarctic plate, and (2) data available for the region encompassing the following Northern African basins: Taoudenni, Al Kufra, Murzuk, Illizi and Sirte.

The database of Cenozoic volcanic – magmatic activity includes virtually all sites on the African plate as well as on part of the adjacent Antarctic plate for which volcanic and / or magmatic activity during the last 65 Ma has been reported. The primary reason to include also data from part of the adjacent Antarctic plate is that the Plume Generation Zone (PGZ; Burke et al. 2008a) extends below the Antarctic plate. One of the goals of the TAP project was to investigate a possible link between Cenozoic African volcanic activity and the PGZ, similar to the link found between the large igneous provinces of the last 300 Ma and the PGZ. We make no a-priori selection based on characteristics such as 'hotspot' related volcanism, rift-related activity, anorogenic magmatism, etc. This Cenozoic part of our database includes over 2500 reported ages. These ages have been determined by the $^{40}Ar/^{39}Ar$ method (N = ~500), the K/Ar method (N = ~1900) or other methods such as U/Pb, Rb/Sr, etc (N = ~100 all together). For a number of areas a large amount of age determinations is available, such as for example for the Canary Islands, Cape Verde and the East African Rift Valley in Kenya and Ethiopia. For several other known volcanic centres far fewer ages are available, such as for example those located in Chad and Sudan.

The 2nd part of the database covers geochronological data available for the region encompassing the Taoudenni, Al Kufra, Murzuk, Illizi and Sirte basins. However, the vast majority of published data are from surface outcrops in areas immediately adjacent to these basins, rather than from the basins themselves. Published data (~900 ages) included in this database are obtained from the following geo-chronological methods: Ar/Ar, K/Ar, Re/Os, Rb/Sr, Sm/Nd, Lu/Hf, FT, U/Pb, Pb/Pb and U-Th/Pb.

A lot of data were first published from the 1960s to 1980s. References to age data in many more recent publications turned out not to be pointing towards these original sources, but to overview papers, geological reviews, etc. The references in the current database are almost exclusively taken from the original sources. It is inevitable, however, that a number of relevant data and references are missing, especially those reported in grey (not peer reviewed) literature.

The quality of the reported ages in both parts of the database is variable, both in terms of analytical precision as well as in, for example, details on sample locations, rock descriptions, etc. Ideally all age determinations would be by modern methodology such as 40Ar/39Ar or U/Pb. K/Ar dating, unlike its follow-up $^{40}Ar/^{39}Ar$ dating, lacks the capability to easily reveal post-eruption isotopic disturbances. However, the K/Ar ages included here are mostly for Cenozoic volcanics and these rocks typically have relatively simple cooling histories (without, for example, metamorphic thermal overprint). There is no obvious reason to expect *systematic* isotopic disturbances across large areas represented in the database. Also, for most known Cenozoic volcanic – magmatic occurrences multiple age determinations are available, so cross-checking these results provides a first level of quality control.

Because of the scale – both geographical and temporal – of our analysis (focussed on the entire African plate) shortcomings in the compilation, such as the lack of GPS coordinates for many datapoints or the use of now-outdated decay-constants, is considered non-critical. When

coordinates were lacking in the original publications, they were estimated based on geological maps included in the publications or for example by using published location maps together with Google Earth.

Descriptions of sample lithology in the references included in the database is often limited to simply a rock name. Nevertheless, this allows us to distinguish alkaline rocks (Sørensen 1974) and carbonatites (ARCs) from other rock types. We use two different definitions here to separate ARC from non ARC: a broad definition by Woolley (2001), which includes nepheline syenites, basanites, peralkaline syenite, quartz syenite, comendite, pantellerite, etc., and a more narrow definition by Kevin C. Burke, which strictly includes nephelinite, nepheline syenite, phonolite and sövite.

2. FIELD NAMES IN THE MICROSOFT ACCESS DATABASE

The electronic supplement to this report is a Microsoft Access database that can be easily linked (dynamically) to ArcGis. It includes the following field names, that will show up when using the 'identify' tool in ArcGis:

General datafields

Sample
Sample name taken from publication, or location name when no sample name was given in the reference

Input_order
Refers to order the data were entered into the database, internal use only

PlateID
Refers to EarthByte PlateIDs (101, North American Craton; 201, South American Craton; 301, Northern European Craton and Eurasia; 501, Indian Craton; 503, Arabia; 701, African Craton; 709, Somalia Plate; 802, Antarctica and East Antarctica; 820, Drake passage South, Scotia Sea)

Time0
Column of zeroes, included for internal use in Gplates reconstruction software only

Location
Location name as given in the reference

Lithology
Lithological name given in the reference

ARC_Woolley
'Yes' if site is included in Woolley (2001)

ARC_Burke_Ashwal
'Yes' if lithology is nephelinite, nepheline syenite, phonolite orsövite

Mineral
Specifies mineral phase dated, or whole rock where appropriate

Stratigraphic age
Stratigraphic age of sedimentary rock, as specfied in original publication

Elevation
Elevation in meters above sea level

Lat
Latitude in decimal degrees

Long
Longitude in decimal degrees

Coordinates
'Reported' when latitude and longitude were reported in the reference; 'Approximate' when latitude and longitude were found using location maps, geological maps, Google Earth, etc.

Method
Isotope geochronological method used in age determination

Age_on_map
Age in Ma to be used for plotting in ArcGis; copied over from the appropriate isotope age

1s_error_on_map
1σ error in Ma to be used for plotting in ArcGis; copied over from the appropriate isotope age error

Classification
Classification of reported age as metamorphic age, emplacement age, cooling age, retrogression age, etc; based on data description and interpretation in publication

U/Pb, Pb/Pb and U-Th-Pb age data

U/Pb, Pb/Pb, U-Th-Pb age
Reported age in Ma based on U/Pb, Pb/Pb or U-Th-Pb isotope system
U/Pb, Pb/Pb, U-Th-Pb 1s
Reported 1σ error in Ma based on U/Pb, Pb/Pb or U-Th-Pb isotope system
U/Pb, Pb/Pb, U-Th-Pb mswd
Mean square weighted deviation on isochron

Lu/Hf age data

Lu/Hf age
Reported age in Ma based on Lu/Hf isotope system
Lu/Hf age 1s
Reported 1σ error in Ma based on Lu/Hf isotope system
176Hf/177Hfi
Initial $^{176}Hf/^{177}Hf$ ratio
176Hf/177Hfi 1s
1σ error on initial $^{176}Hf/^{177}Hf$ ratio
Lu/Hf mswd
Mean square weighted deviation on isochron

Re/Os age data

187Os/188Os initial
Initial $^{187}Os/^{188}Os$ ratio
187Os/188Os initial 1s
1s error on $^{187}Os/^{188}Os$ ratio
Re-Os age
Re-Os age in Ma
Re-Os error
1σ error on Re-Os age in Ma
Re-Os MSWD
Mean square weighted deviation on isochron

Rb/Sr age data

87Sr/86Sr0 (Rb/Sr)
Initial $^{87}Sr/^{86}Sr$ ratio
87Sr/86Sr0 1s (Rb/Sr)
1σ error on initial $^{87}Sr/^{86}Sr$
MSWD Rb/Sr
Mean square weighted deviation on isochron
Isochron age, Rb/Sr
Rb/Sr age in Ma
Error 1s, Rb/Sr
1σ error on Rb/Sr age in Ma

Sm/Nd age data

Sm/Nd age
Reported Sm/Nd age in Ma
Sm/Nd 1s error
1σ error in Ma on Sm/Nd age
143Nd/144Ndi
Initial $^{143}Nd/^{144}Nd$ ratio

143Nd/144Ndi 1s
1σ error on initial $^{143}Nd/^{144}Nd$ ratio
Sm/Nd MSWD
Mean square weighted deviation on isochron

K/Ar age data
40Ar radiogenic (scc/g)
Standard cm^3 of ^{40}Ar per gram of sample material
40Ar radiogenic/40Ar total (%)
Radiogenic ^{40}Ar / ^{40}Ar total ratio in %
K2O%
Weighted percent of K_2O in sample material
Apparent age
Reported apparent K/Ar age in Ma
error
1σ error on reported K/Ar age in Ma

$^{40}Ar/^{39}Ar$ age data
Age
Reported $^{40}Ar/^{39}Ar$ age in Ma
Error 1s
1σ error on reported $^{40}Ar/^{39}Ar$ age in Ma
40Ar_39Ar_preferred_age_calculation_method
Specifies whether the reported $^{40}Ar/^{39}Ar$ age is a plateau age, weighted mean age or inverse isochron age
40Ar_39Arage_from_other_calculation_method
Specifies type of alternative calculation method, in case one was reported
Other_40Ar_39Arage_value
$^{40}Ar/^{39}Ar$ age in Ma from alternative calculation method, in case one was reported
Other_40Ar_39Arage_error_1s
1σ error on $^{40}Ar/^{39}Ar$ in Ma from alternative calculation method, in case one was reported
Percent39Ar_spectrum_age
Percentage of cumulative ^{39}Ar included in the preferred age calculation
40Ar36Ar_inverse_isochron_intercept
$^{40}Ar/^{36}Ar$ ratio for the intercept in the inverse isochron diagram
40Ar36Ar_inverse_isochron_intercept_1s_error
1σ error on the $^{40}Ar/^{36}Ar$ ratio for the intercept in the inverse isochron diagram
MSWD_ArAr
Mean square weighted deviation on inverse isochron

Fission track age data
rhoDx10e6/cm2
Track density in millions per square centimeter in the mica covering the dosimeter glass
ND
Number of tracks counted in the mica covering the dosimeter glass
rhoSx10e6/cm2
Spontaneous track density in millions per square centimeter in the etched sample
NS
Number of spontaneous tracks counted in the etched sample
rhoIx10e6/cm2
Induced track density in the mica covering the etched sample

NI
Number of induced tracks counted in the mica covering the etched sample
Dispersion
Degree of variability in a probability distribution, in %
P(X)2
Chi-squared probability of the fission track sample age
FTPage
Pooled fission track age in millions of years
FTPage_1s
1σ error on the pooled fission track age in millions of years
FTCage
Central fission track age in millions of years
FTCage_1s
1σ error on the central fission track age in millions of years
grains
Number of grains in which spontaneous tracks were counted
MTL
Mean track length of spontaneous fission tracks in microns
MTL 1s
1σ error on the mean track length of spontaneous fission tracks in microns
MTL SD
Standard deviation of the track length distribution of spontaneous fission tracks
No tracks
Number of tracks for which track length was measured
Dpar
Diameter of etch pit measured parallel to the crystallographic c-axis
Dpar SD
Standard deviation on the distribution of etch pit size measured parallel to the crystallographic c-axis

Literature reference information, comment
Interpretation, comment
Interpretation of the reported age in the referenced paper, including comment (where applicable)
Primary reference
Details of the reference in which data were originally reported
Secondary reference
Details of references that include citations papers not individually verified

3. GEOCHRONOLOGICAL DATABASE FOR CENOZOIC VOLCANIC & MAGMATIC EVENTS

This compilation includes all reported geochronological data on Cenozoic volcanic and magmatic events on the African plate and part of the adjacent Antarctic plate. Most of these data were obtained with the K/Ar method. Many of these datapoints are from the so-called volcanic swells (Burke et al. 2008a) on the African and Antarctic plates. When the locations of these volcanics are compared to the location of the so-called Plume Generation Zone (the 1% slow shear wave velocity boundary at the Core-Mantle Boundary, or Large Low Shear Velocity Provinces – LLSVP), it is apparent that there is a relationship between the two (Fig. 1). This relationship has previously been established for Large Igneous Provinces of the last 300 Ma (Burke et al. 2008b). Volcanic rocks related to opening of for example the Red Sea and the East African Rift Zone do not fit this pattern.

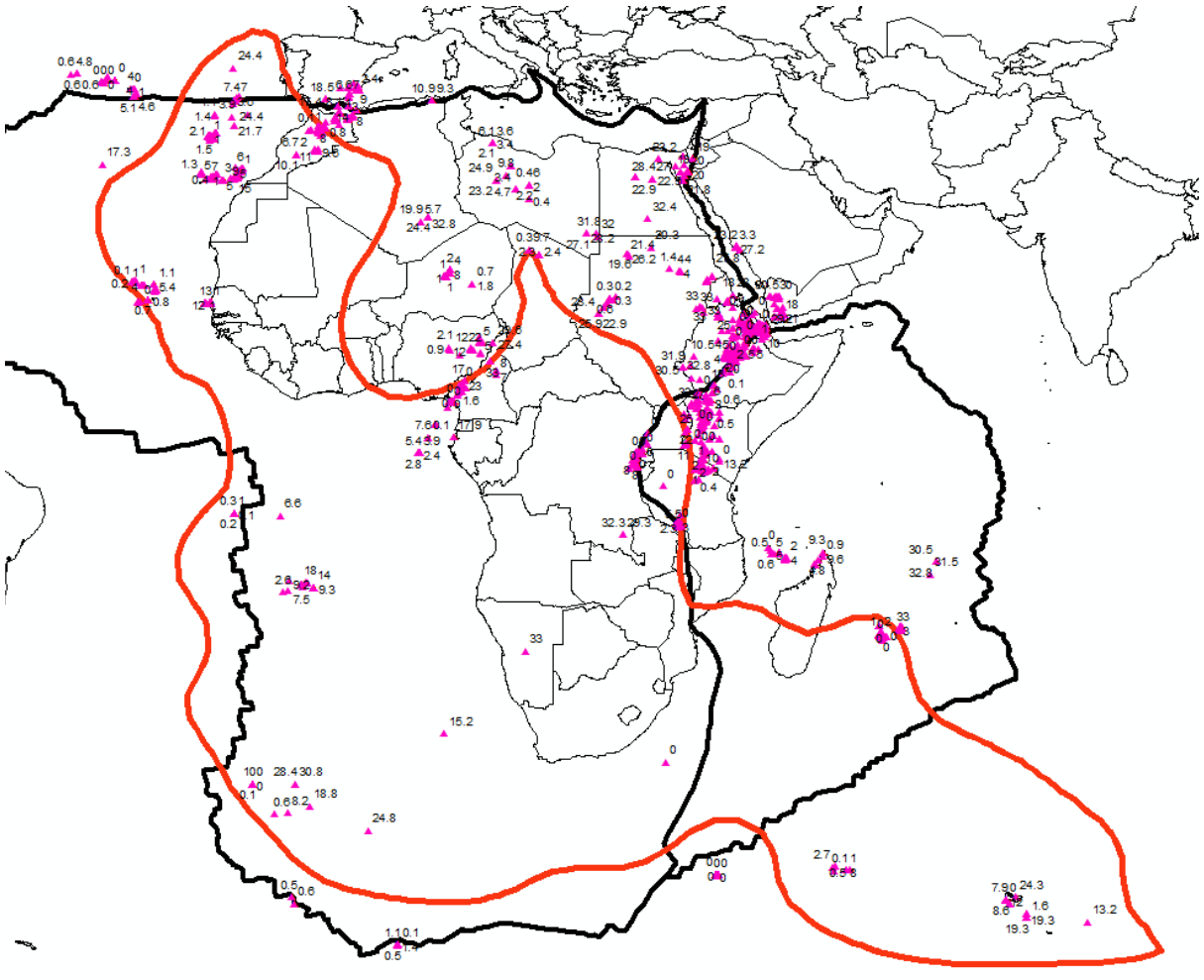

Figure 1. Volcanic rocks younger than 30 Ma on the African plate and part of the adjacent Antarctic plate. Red line representing the 1% slow shear wave velocity boundary at the Core-Mantle Boundary

To select Cenozoic volcanic and magmatic events from the MS Access database file the following query can be used in ARCgis:

Age_on_map <=65 AND Classification = 'Emplacement age'

To select alkaline rocks from this database (Woolley definition) the following query can be used:

Age_on_map <=65 AND Classification = 'Emplacement age' AND ARC_Woolley = 'ARC'

To select alkaline rocks from this database (Burke's narrow definition) the following query can be used:

Age_on_map <=65 AND Classification = 'Emplacement age' AND ARC_Burke_Ashwal = 'ARC'

4. GEOCHRONOLOGICAL DATABASE FOR SELECTED NORTHERN AFRICAN BASINS

The compilation at present includes geochronological data available for the following Northern African basins: Taoudenni, Al Kufra, Murzuk (Murzuq), Illizi and Sirte. Basin outlines in the accompanying figures are according to Hemsted, Geological Society, London, Special Publication, V207, 9 – 20 (2003).

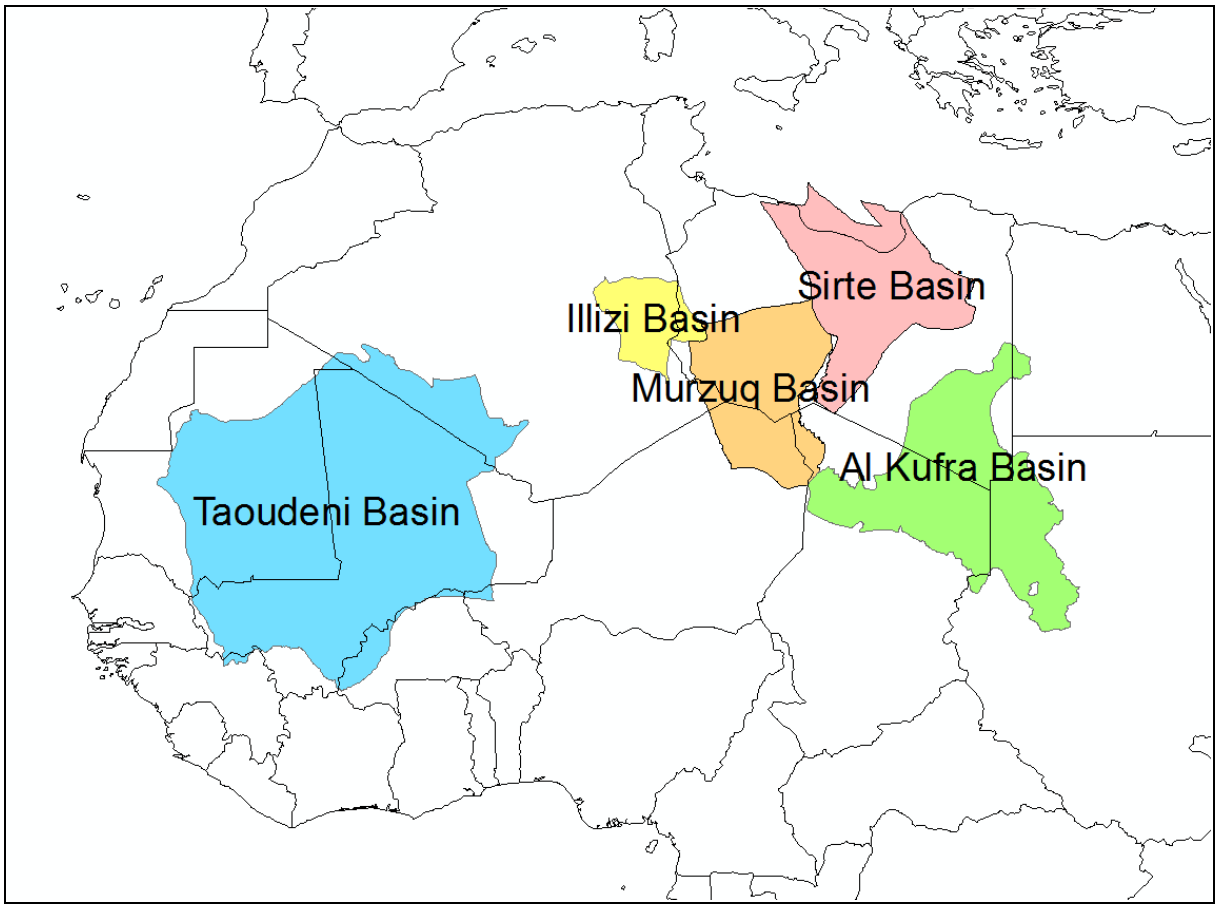

Figure 2. Northern African basins selected for inclusion in the geochronology database

4.1 TAOUDENNI BASIN

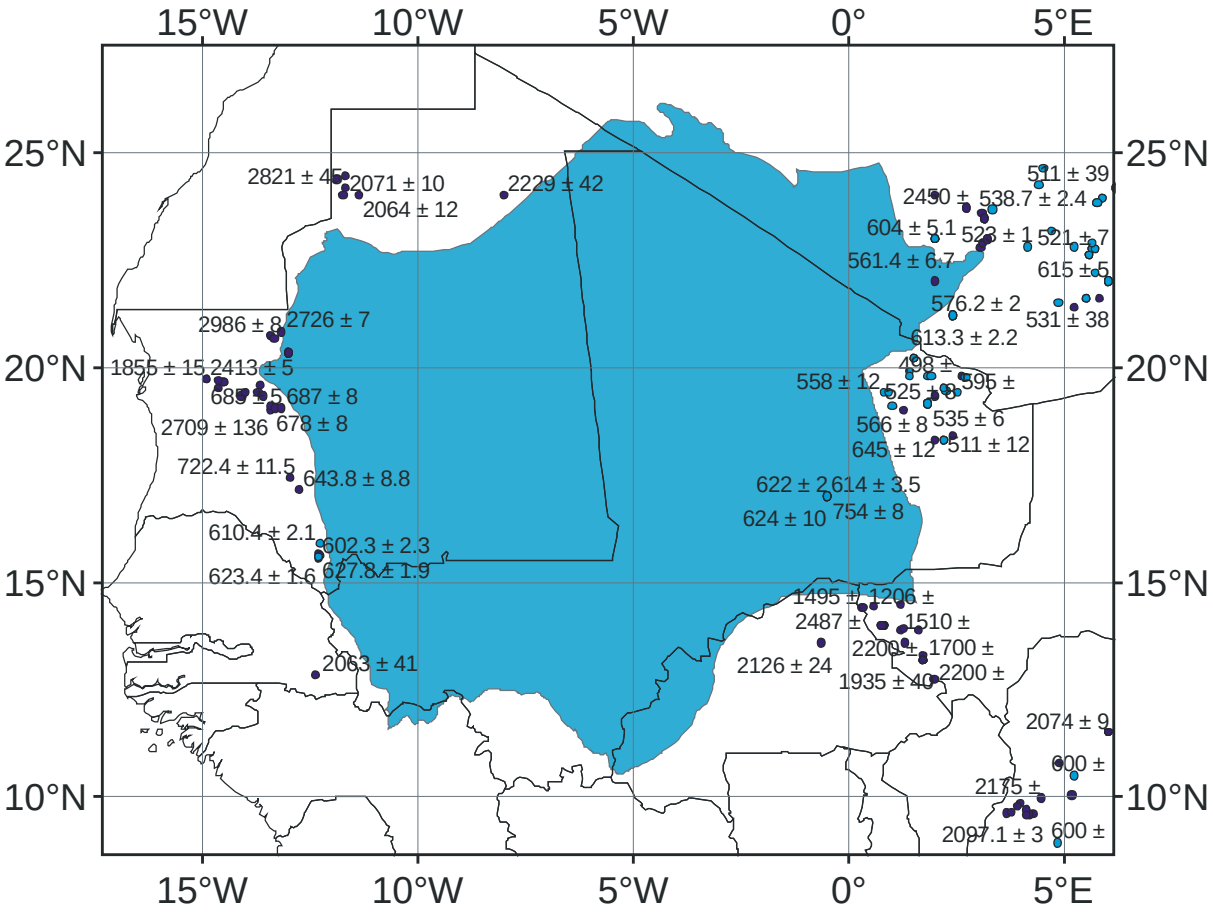

Figure 3. Crystalline basement ages (incl. Pan-African) for the Taoudenni basin area

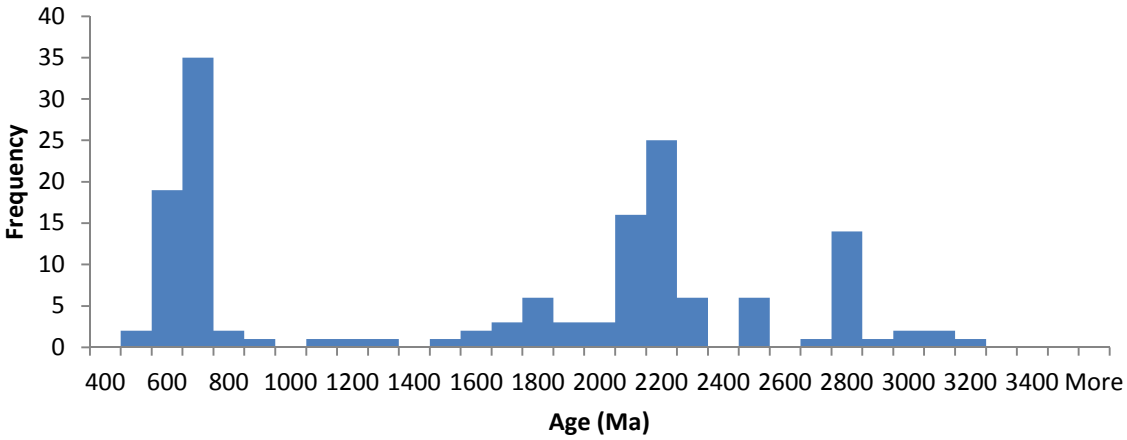

Figure 4. Histogram for crystalline basement ages (incl. Pan-African) for the Taoudenni basin area

Crystalline basement ages for the Taoudenni basin area mostly reflect 4 geological episodes. Archaean ages are found in the west, in Mauritania. Palaeoproterozoic Birimian ages are found all around the Taoudenni basin area, and ages indicating Eburnian rejuvenation at ~1.8 – 2.0 Ga are found everywhere where Birimian ages are found. Pan-African ages are found almost exclusively east of the Taoudenni basin area, in the Trans-Saharan belt.

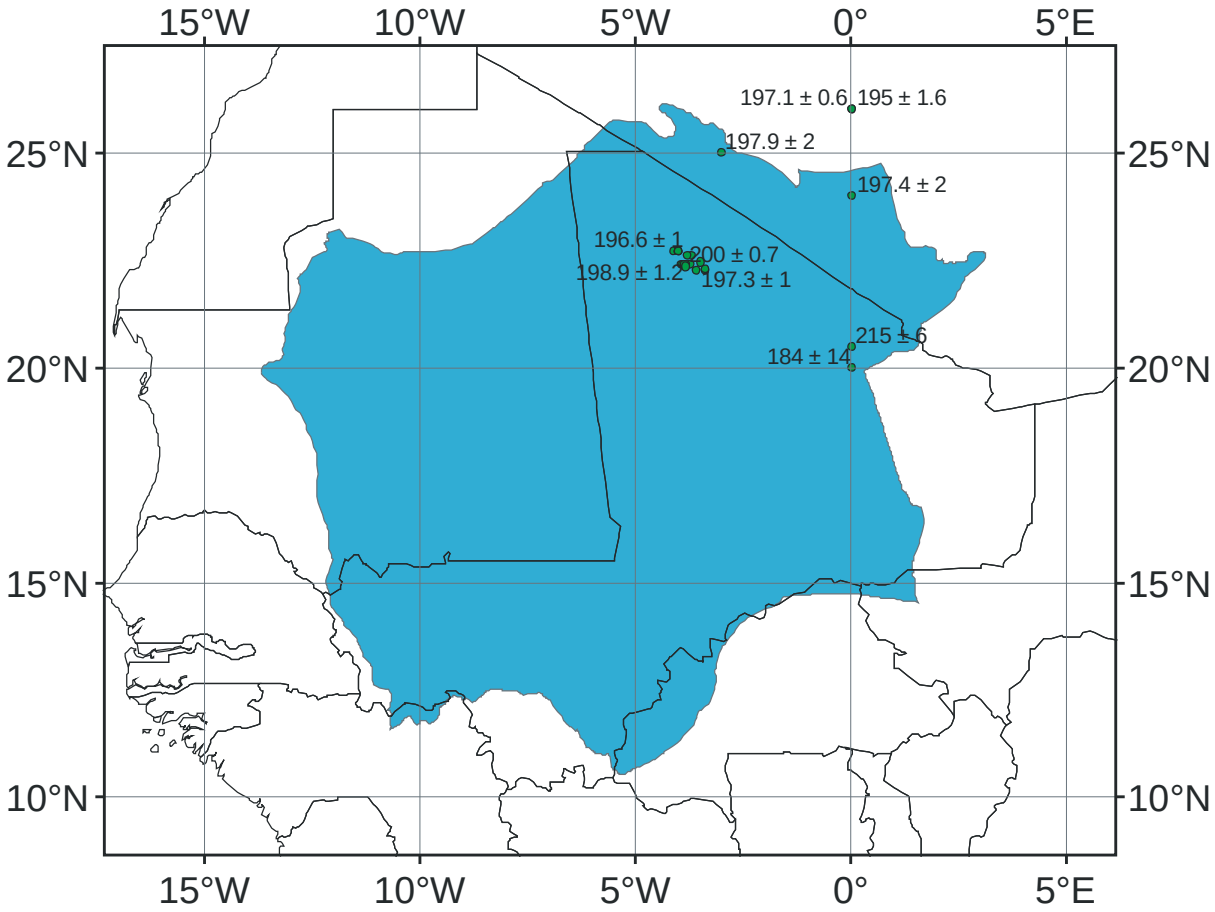

Figure 5. Central Atlantic Magmatic Province (CAMP) ages in the Taoudenni basin area

CAMP ages (intrusive at ~198 – 200 Ma) are reported for the northwestern part of Mali, along the border with Algeria. Basaltic lavas and sills assumed to be of CAMP age are also present in the northwestern part of the Taoudenni basin area, but no actual age constraints have yet been found.

Late Hercynian metamorphic ages are found along the western boundary of the Taoudenni basin area, in the Northern and Southern Mauritanide orogen (Fig. 6 and 7). The available ages here appear to represent two populations (330-300 Ma and 280-260 Ma). However, the number of ages are too few to conclude that these reflect two separate geological events, rather than a single, protracted metamorphic episode.

No Cenozoic volcanic rocks are found in the Taoudenni basin area.

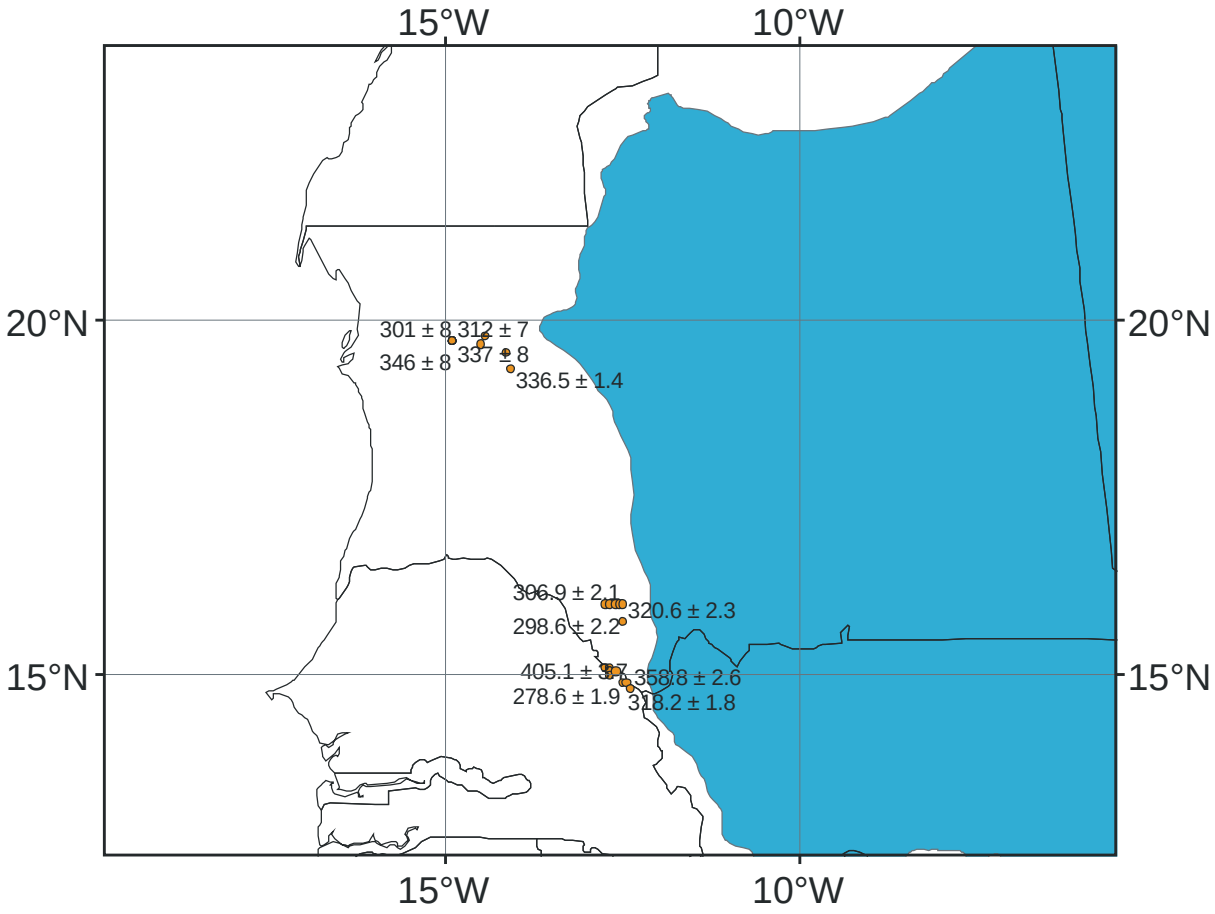

Figure 6. Late Hercynian metamorphic ages of the Mauritanides

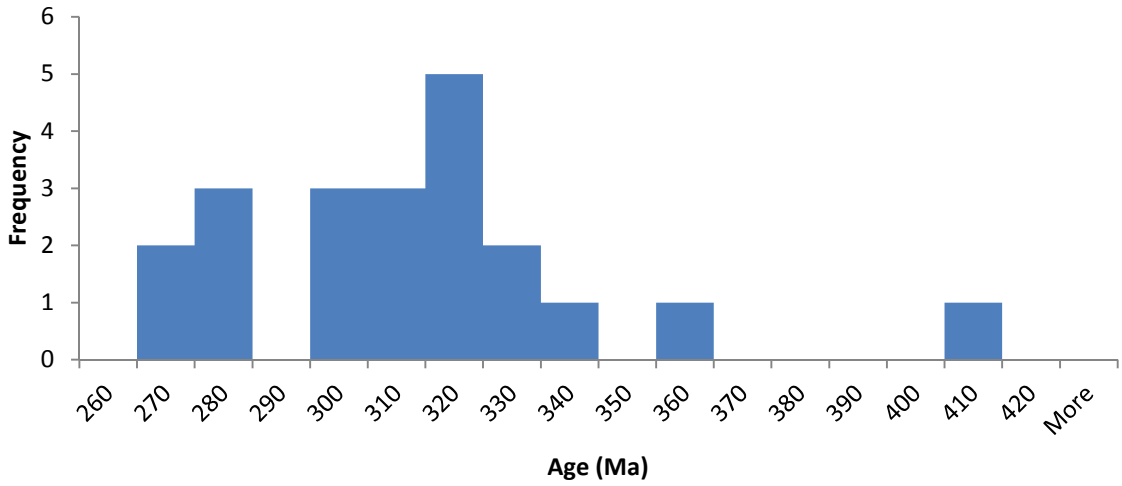

Figure 7. Histogram of metamorphic ages of the Southern and Northern Mauritanides

4.2 AL KUFRA, MURZUK, ILLIZI AND SIRTE BASINS

Crystalline basement ages in the area encompassing the Al Kufra, Murzuk, Illizi and Sirte basins reflect the same Paleoproterozoic episodes found in the Taoudenni basin area (Fig. 8). In addition, a significant number of Late Proterozoic ages are found in the Ahaggar region, Tibesti area and the Bayuda desert (0.8 Ga – 1.1 Ga). Pan-African ages are reported towards the west and southwest of the Illizi and Murzuk basins, in the Trans-Saharan belt (Fig. 9).

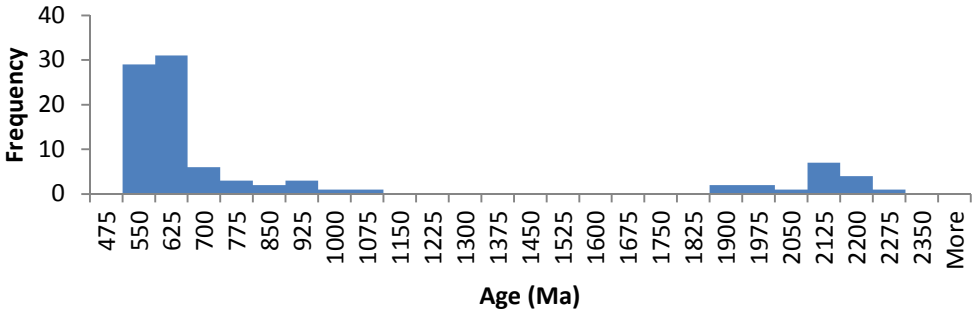

Figure 8. Histogram of crystalline basement ages in the region encompassing the Al Kufra, Illizi, Sirte and Murzuk basins.

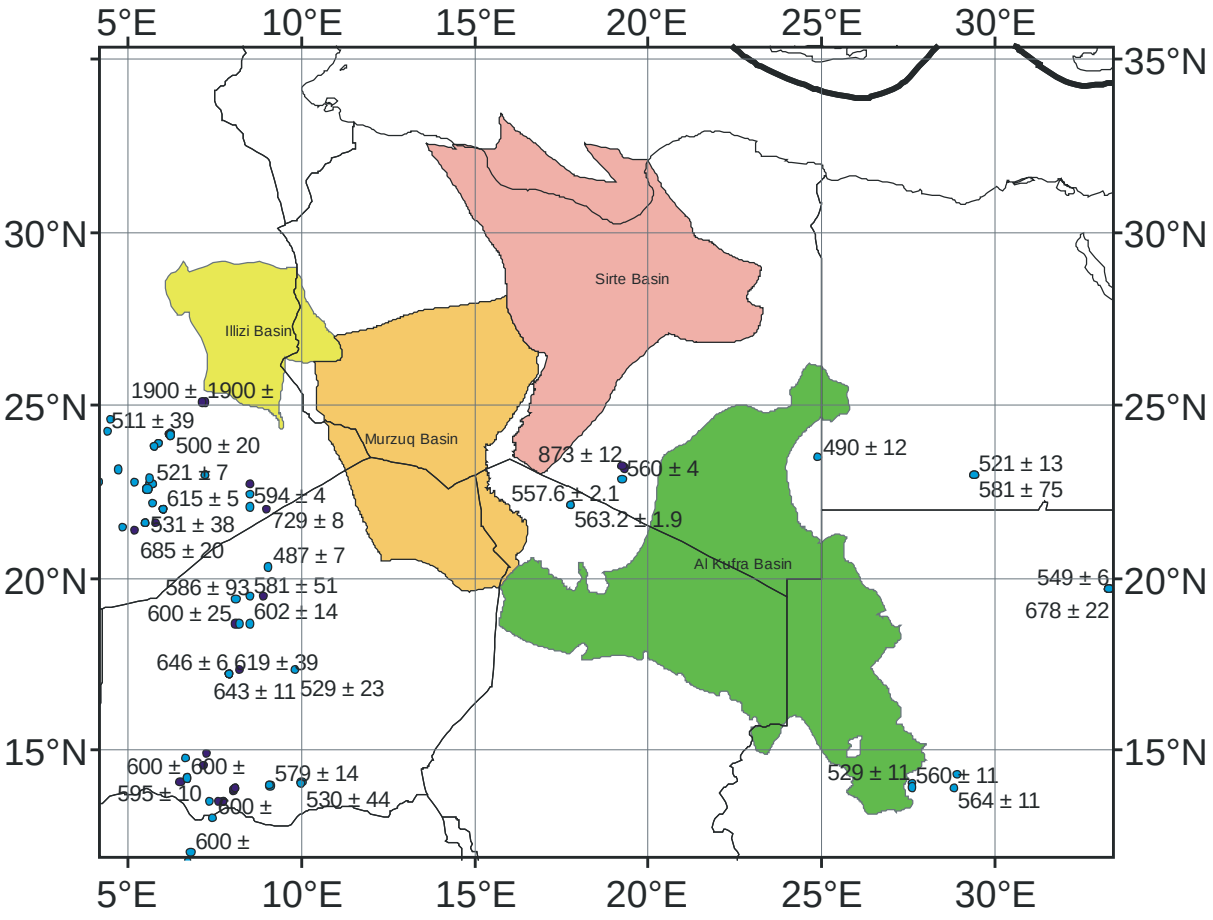

Figure 9. Sample locations for crystalline basement ages in the region encompassing the Al Kufra, Illizi, Sirte and Murzuk basins.

Post Pan-African ages in this region are mostly Cenozoic volcanic rocks. In addition, K-Ar ages from ring complexes and fault systems along the southeastern end of the Al Kufra basin are mostly Triassic, with some Jurassic ages nearby and some Permian ages further away (Fig. 10)

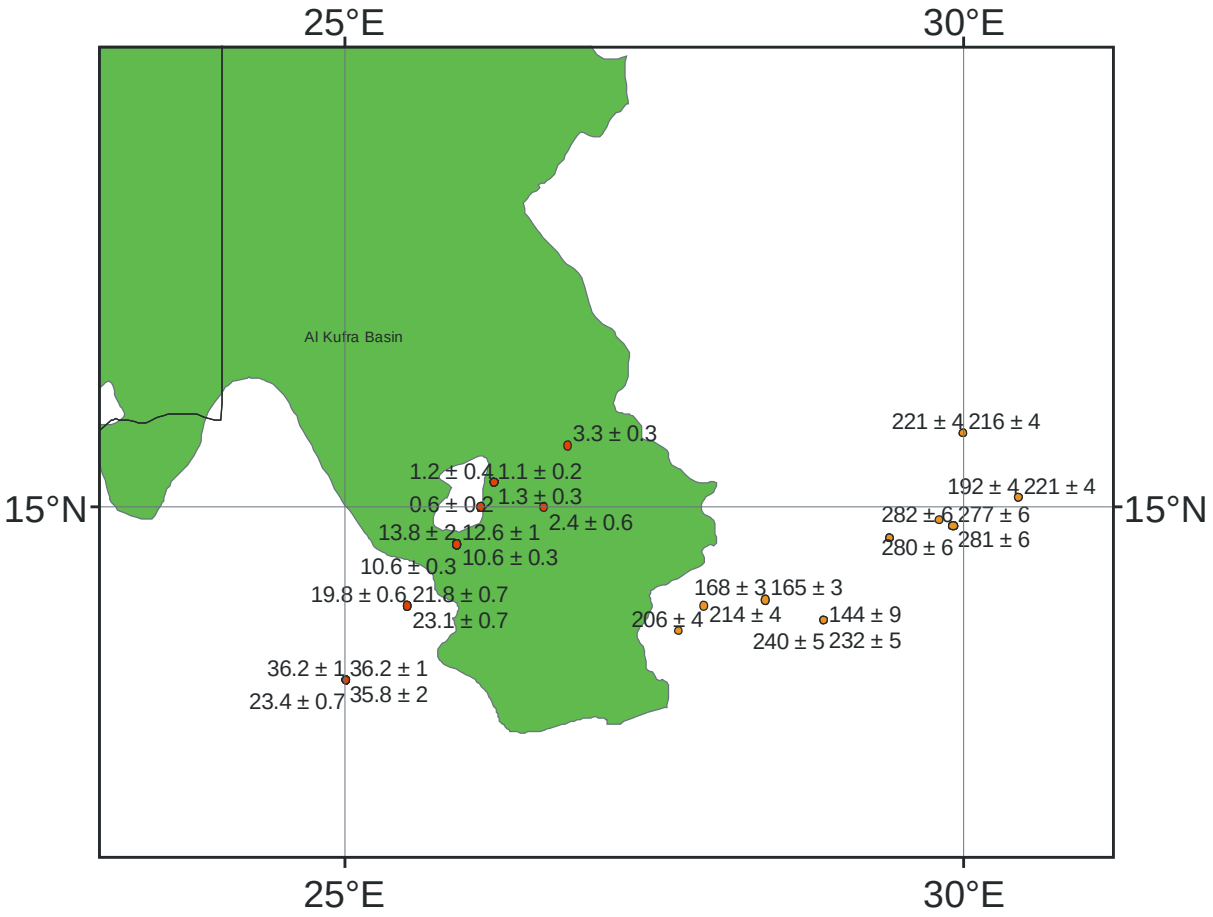

Figure 10. Southeastern section of the Al Kufra basin (Sudan)

Cenozoic volcanic rocks are found all around Al Kufra, Sirte, Illizi and Murzuk. The following ranges of ages have been reported (mostly K-Ar), see Fig. 10:
Garian: 2.1 – 6.1 Ma
Jebel Soda: 10.5 – 12.3 Ma
Al Haruj: 3.4 -10.2 Ma
Ahaggar: 24.4 – 44.0 Ma
Aïr: 0.8 – 1.8 Ma
Tibesti: 1.3 – 2.4 Ma
Uweinat: 37.9 – 54.0 Ma
Darfur: 0.6 – 35.8 Ma (and everything in between, generally increasing from NE-SW)
Laqia Arbain and Laqia: 19.6 – 26.2 Ma

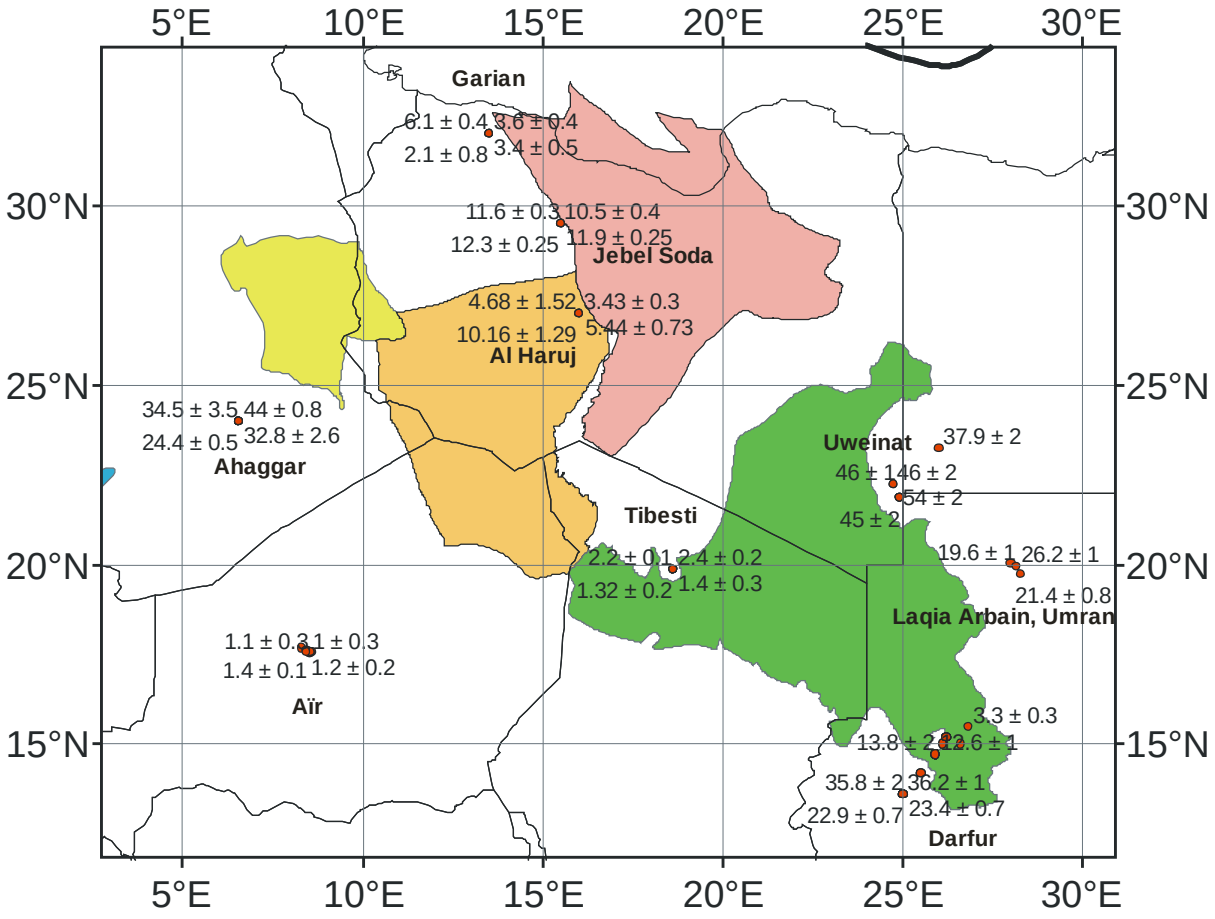

Figure 11. Cenozoic volcanics in the Al Kufra, Illizi, Sirte and Murzuk basin area.

The Cenozoic volcanic rocks (mostly 30 Ma and younger) found in Northern Africa are part of a much larger pattern of young volcanic rocks on the African plate, and even the Antarctic plate.

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