

February 19, 2024

## News and notes

Before going on to discuss the geology and geopolitics of [Chad](#), here are some news items I thought were interesting.

## Research

- Two new studies on fluvial geology, [here](#) and [here](#); Phys.org summary [here](#).
- More fluvial geology: [Autogenic evolution of valley-confined deltas during sea-level rise: Insights from numerical and physical modelling](#).
- [Origin, evolution and significance of giant buried sediment mounds near the Sahara Slide Complex, North-west African margin](#).
- [Grain-size component dependent storage threshold of orbital cycles in alluvial stratigraphy caused by autogenic dynamics](#).
- Geological history and stable isotope analysis: [Oxygen isotope ensemble reveals Earth's seawater, temperature, and carbon cycle history](#); Phys.org summary [here](#).
- Pretty, shiny things: [Chemically Oscillating Reactions as a New Model for the Formation of Mineral Patterns in Agate Geodes and Concretions](#).
- Geological mapping research: [Machine Learning-Based Lithological Mapping from ASTER Remote-Sensing Imagery](#).
- Stratigraphy: [Align: A User-Friendly App for Numerical Stratigraphic Correlation](#).
- Mineralogy of rock formation: [Mantle depletion recorded by olivine and plagioclase megacrysts in oceanic basalts](#).
- Greenland becoming greener: [Land cover changes across Greenland dominated by a doubling of vegetation in three decades](#); Phys.org summary [here](#).

## Plate Tectonics

- [Gibraltar subduction zone is invading the Atlantic](#); behind a paywall, Phys.org summary [here](#).
- Summary of Hawaiian Islands plate tectonics: [The Hawai'i chain of islands is migrating toward extinction](#).
- Nitrogen cycles and plate tectonics: [Fluid loss to the fore-arc controls the recycling efficiency of nitrogen in subduction zones](#).
- [Delineation of an exhumed intermediate-depth crustal fault in a collisional setting: An example from the Himalaya](#).

- [Paleozoic evolution of the Yukon-Tanana terrane of the North American Cordillera, NW British Columbia.](#)
- [Hydrothermal Degassing Through the Karakoram Fault, Western Tibet: Insights Into Active Deformation Driven by Continental Strike-Slip Faulting.](#)
- [Artificial age-independent seismic anisotropy, slab thickening and shallowing due to limited resolving power of \(an\)isotropic tomography.](#)
- [Toroidal mantle flow beneath the NE termination of the Kuril–Kamchatka subduction zone from seismic anisotropy.](#)

## Paleontology

- [Discovery of modern living intertidal stromatolites on Sheybarah Island, Red Sea, Saudi Arabia.](#)
- Mass extinction research: [Atmospheric ozone destruction and the end-Permian crisis: Evidence from multiple sulfur isotopes](#); Phys.org summary [here](#).
- [Genomes, fossils, and the concurrent rise of modern birds and flowering plants in the Late Cretaceous](#); Phys.org summary [here](#).
- Lecture on You Tube: [Wonders of the Jurassic Coast – with Dr Anjana Khatwa at Ada Lovelace Day.](#)
- [Locomotion and the early Mesozoic success of Archosauromorpha](#); Live Science summary [here](#).
- [A new small duckbilled dinosaur \(Hadrosauridae: Lambeosaurinae\) from Morocco and dinosaur diversity in the late Maastrichtian of North Africa](#); SciNews summary [here](#).
- Fraud revealed: [Forged soft tissues revealed in the oldest fossil reptile from the early Permian of the Alps](#); Science Alert summary [here](#).

## Mining and Energy

- [SSR Mining SVP is latest company figure detained over mine disaster](#); related: [Turkey cancels SSR gold environmental permits after accident](#).
- Mining Research: [Tailings Behavior Assessment Using Piezocone Penetration Test](#).
- More mining research: [An analysis of the Impact of Mining Excavation Velocity on the Development of Gaseous and Gaseous Geodynamic Hazards in Copper Ore Mines](#).
- NW Ontario: [Côté Gold mine set to enter production in March](#).
- [Valentine Gold Mine report released on Valentine’s Day](#).
- [Hecla’s 2023 silver production the second highest in history, more growth expected](#).
- [The world’s next high-grade copper mine is nearing construction](#).

- [Global Uranium Reserves, by Country](#); related: [Three Countries Hold 50% of the World's Uranium Reserves](#).
- Saskatchewan: [SRC VP confident government-funded rare earth processing facility will 'turn a profit'](#).
- [The first cobalt refinery in North America is in Canada](#); won't be using [child labour](#).
- [Column: West challenges China's critical minerals hold on Africa](#); where they use child labour.
- [The Raw Material Challenge of Creating a Green Economy](#).
- [Federal Court allows judicial review of southern Alberta coal mine denied by panel](#).
- [Oil Prices in Limbo as Geopolitical Risks Fail to Offset Bearish Sentiment](#).
- [Firms Hike Spending on Oil and Gas Activity Offshore Norway in 2024](#).
- [Canadian First Nation sends notice of opposition to Obsidian Energy drilling plans](#).
- [Why refurbishing the Pickering nuclear plant is the right move for Ontario](#).
- [Advanced geothermal drilling is 70% faster and 50% cheaper than 2022](#).

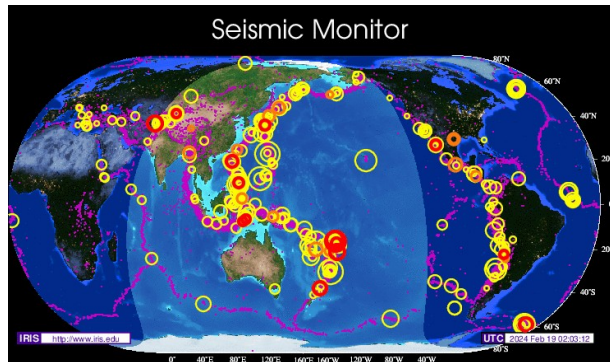
## Environmental Geology and Hydrogeology

- [Widespread contamination of soils and vegetation with current use pesticide residues along altitudinal gradients in a European Alpine valley](#).
- [The Fraud of Plastic Recycling](#); The Guardian summary [here](#).
- [A pilot study of chlormequat in food and urine from adults in the United States from 2017 to 2023](#); quote: "exposure to chlormequat can reduce fertility and harm the developing fetus"
- [Implementing vanadium peroxides as direct air carbon capture materials](#); Phys.org summary [here](#).
- New York times: [Montana Court Restricts Use of Groundwater for New Homes](#).
- [Slowly but surely: Exposure of communities and infrastructure to subsidence on the US east coast](#); Ars Technica summary [here](#).
- [Groundwater Abstraction has Caused Extensive Ecological Damage to the Doñana World Heritage Site, Spain](#); Phys.org summary [here](#).
- Free book from the Groundwater: [History and Hydraulics of Flowing Wells](#).

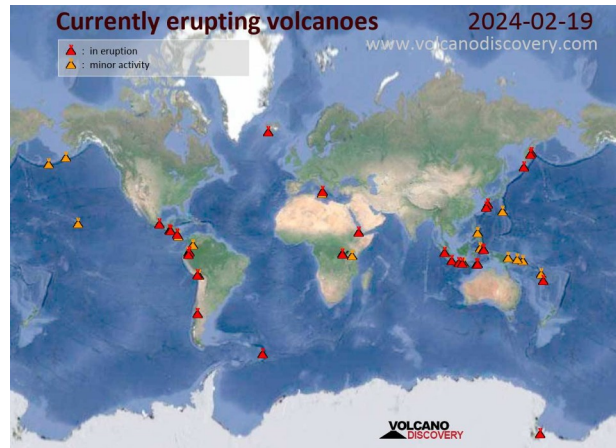
## From Out of this world

- Plate tectonics on Mars: [Diverse volcanism and crustal recycling on early Mars](#); Ars Technica summary [here](#).
- Meteorite mineralogy: [Chondritic chlorine isotope composition of acapulcoites and lodranites](#).

## Volcanoes, Earthquakes and Geohazards



[Seismic Monitor](#)



[Active Volcano Map](#)

- United States Geological Survey (USGS) Volcano Watch: [Dear Valentine, will you be my lab partner?](#)
- USGS Yellowstone Volcano Observatory: [Irving Friedman: Pioneer on the global water cycle, Yellowstone's magma-hydrothermal system, and more.](#)
- [Smithsonian / USGS Weekly Volcanic Activity Report.](#)
- [Euro-Mediterranean Seismological Centre](#)
- Iceland:
  - You Tube video: [Spectacular New Volcanic Eruption In Iceland](#);
  - [2021–2023 Unrest and Geodetic Observations at Askja Volcano, Iceland](#);
  - [So Much Lava Is Oozing Out Of Iceland That You Can See It From Space.](#)
- Hidden magma chamber: [The Crustal Magmatic Structure Beneath the Denali Volcanic Gap Imaged by a Dense Linear Seismic Array](#); Live Science summary [here](#).
- [New Zealand earthquake, February 13, 2024.](#)
- [M4.7 earthquake rattles southern Texas.](#)
- Earthquakes and landslides: [Toward the Rapid Seismic Assessment of Landslides in Coastal Alaska.](#)
- Landslides: [3 multimillion-dollar homes teetering on edge of California cliff after landslide, footage shows.](#)
- Video on geophysical hazard: [Are We Ready for Upcoming Geomagnetic Reversal?](#)

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## Geology and the Fate of Societies – Chad



**Figure 1 – The Republic of Chad**  
**Credit: [CIA World Factbook – Chad](#), public domain**

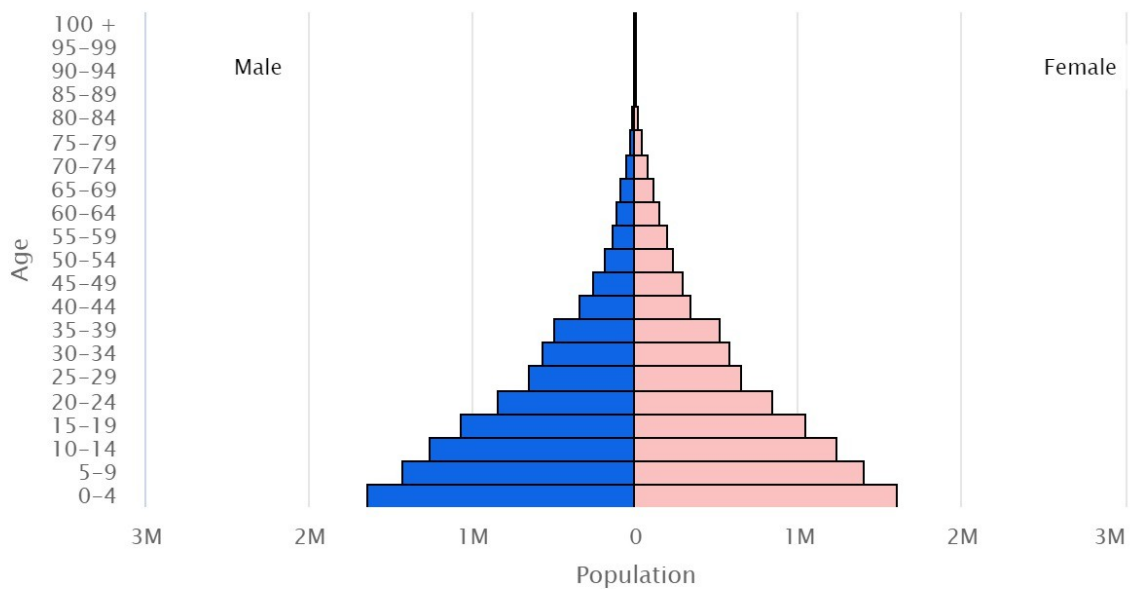
Last week we looked at the [Central African Republic](#), this week we'll take a look at their neighbour, the Republic of [Chad](#). According to the American [Central Intelligence Agency \(CIA\) World Factbook on Chad](#), the country has a total area of 1.284 million square kilometres (km<sup>2</sup>) of which 1,259,200 km<sup>2</sup> is land and 24,800 km<sup>2</sup> is water. Beginning in the north and going clockwise Chad's neighbours are, [Libya](#), [Sudan](#), the [Central African Republic](#), [Cameroon](#), [Nigeria](#) and [Niger](#). Chad is landlocked.

Also according to the [CIA World Factbook](#), Chad has a population of 18,523,165. The population is ethnically diverse and includes: 26.6% [Sara](#); 12.9% [Arab](#); 8.5% [Kanembu](#); 7.2% [Masalit](#); 6.9% [Toubou](#); 4.8% [Masa](#); 3.7% [Bidiyo](#); 3.7% [Bulala](#); 3.0% [Maba](#); 2.6% [Daju](#); 2.5% [Mundang](#); 2.4% [Gabri](#); 2.4% [Zaghawa](#); 2.1% [Fula](#); 2.0% [Tupuri](#); 1.6% [Tama](#); 1.4% [Karo](#); 1.3% [Bagirmi](#); 1.0% [Masmaje](#); 2.6% [other Chadian](#); and 0.7% foreign. Each of the various ethnic groups has their own language; however there are three official languages in Chad: [French](#), [Arabic](#) (in the north) and [Sara](#) (in the south).

The majority, 52.1%, of the people in Chad are [Muslim](#). Of the remainder, 44.2% are Christian, 0.3% follow animist religions, and the remaining 3.2% have no or unspecified religion.

The [demographic profile of Chad](#), Figure 2, shows a young country with 65% of the population under the age of 25. Fertility is high, with 5.35 births per woman. Mortality is also high, with an average life expectancy of 59.6 and a high under-5-mortality rate of 105.3 per 1,000.

Chad (2023)



U.S. Census Bureau, International Database

Figure 2 – Demographic Profile – Chad

Credit: [United States Census Bureau](#), [International Database](#), [Chad](#), public domain

Chad is ruled by a [military junta](#). The Transitional President is [Mahamat Déby](#), the Prime Minister is [Succès Masra](#) and the Vice President is [Djimadoum Tiraina](#). The Capital and largest city is [N'Djamena](#) (pop. 807,000).

## Geology

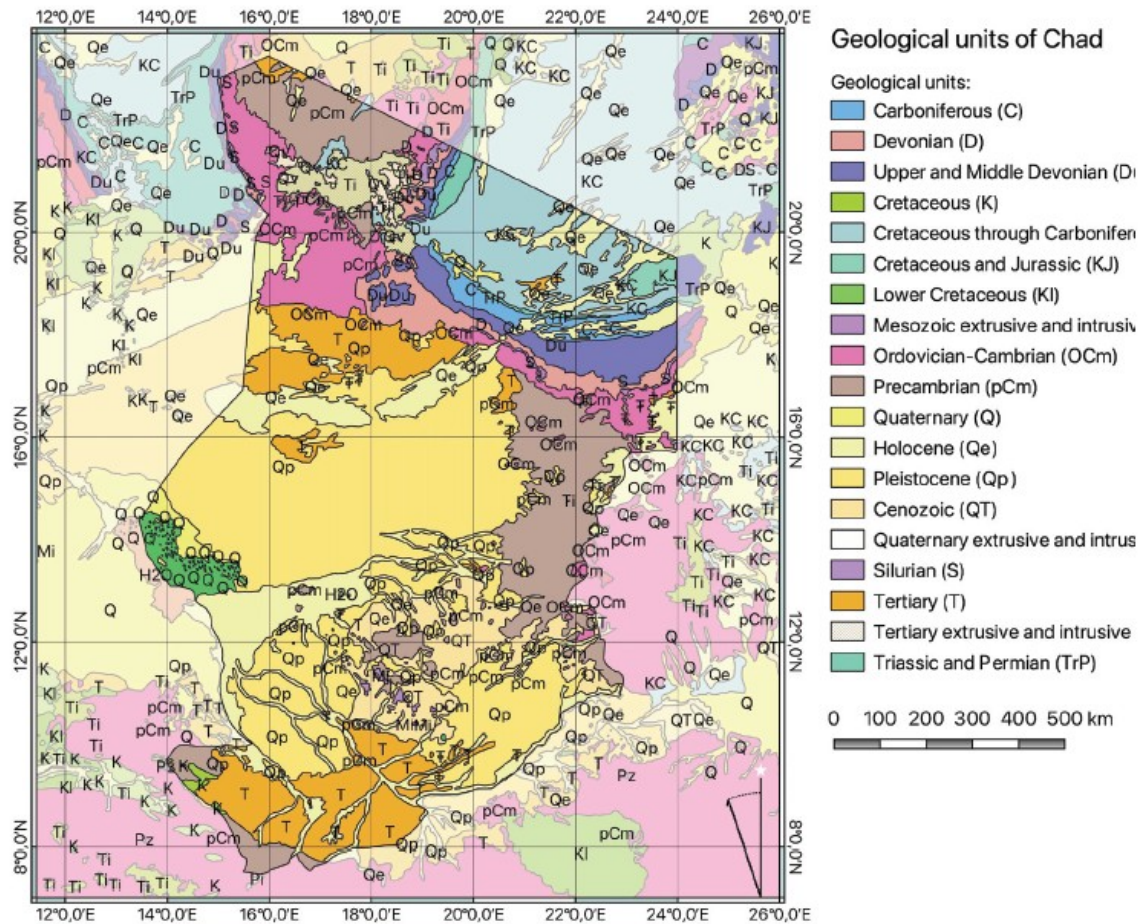


Figure 3 – Geologic Units of Chad

Credit: Figure 2 in [Lemenkova, 2023, Creative Commons Attribution-NonCommercial-NoDerivs 3.0 Unported](#)

Figure 3 shows the geological units of Chad. The oldest rocks in Chad are [Precambrian](#) aged [metamorphic rocks](#). The [Tibesti](#) Mountains in the north includes Precambrian and [Paleozoic](#) deposits. Many of the Precambrian rocks are [granitic gneiss](#) and [pelitic-graphitic schists](#). Younger granites and [pegmatite](#) intrusions are also common.

The deposits of the [Kufra Basin](#), in the northeast, are lower [Palaeozoic](#) sandstones which are overlain by [Nubian Sandstones](#). There are also lower [Cretaceous](#) aged continental [clastic](#) rocks and rocks of [Upper Cretaceous](#) marine deposits.

The youngest deposits in Chad are those of the [Chad Basin](#) which consists of [Paleogene](#), [Neogene](#) ([Tertiary](#)), and [Quaternary sediments](#); the Neogene [Chad Formation](#) is composed of [lacustrine](#) sediment.

This is a very brief summary of the geology. For further reading, I am going to recommend the excellent summary of the geology of Chad in: Lemenkova, P., 2023, [Using open-source software GRASS GIS for analysis of the environmental patterns in Lake Chad, Central Africa](#), Journal of Land Management, Food and Environment, Volume 74, Issue 1, 49–64

## Resources

### Agriculture



**Figure 4 – Agriculture in Chad**  
**Credit: [Voice of America \(VOA\)](#), [public domain](#)**

[Agriculture in Chad](#) employs 80% of the labour force, uses 39.6% of the land (pasture: 35.7%, arable land 3.9%) and constitutes 52.3% of the national economy. Much of the agriculture is for [subsistence](#). You can find statistics from the [United Nations Food and Agriculture Organization](#) (FAO) on food production in Chad are [here](#).

[Arable agriculture](#) in Chad produces mostly [sorghum](#); [peanuts](#); [millet](#); [yams](#); [sugarcane](#); [maize](#); [cassava](#); [rice](#); [sweet potato](#); [sesame seed](#); [beans](#); and [cotton](#). Cotton and sugarcane are grown as cash crops, the rest are for subsistence.

[Livestock production](#) in Chad is a major user of land and employs about a third of the people. Animals raised for food include [cattle](#), [goats](#), [sheep](#), and [poultry](#). Draft animals raised include [camels](#) and [water buffalo](#). Another important source of animal food in Chad, especially around Lake Chad, is [fishing](#). Most of the fish are used locally, although some are sold as dried fish.

As a country mostly dependent on subsistence agriculture, food security is a problem. The [World Food Program](#) estimates that 42 percent of its population lives below the poverty line and that 2.1 million people in Chad were acutely food insecure in 2023.

## Mineral Resources



Figure 5 – Natron Deposit in Chad

Credit: Alexios Niarchos, [Creative Commons Attribution-Share Alike 4.0 International](#) license

Historically, the [mineral industry in Chad](#) consisted of the mining of natron, sodium carbonate. Natron deposits are located around the shore of [Lake Chad](#), in the dry river beds ([wadis](#)) of [Kanem Prefecture](#), and near the of [Faya-Largeau](#) oasis. These deposits were historically, and continue to be, mined on a small, artisanal, basis.

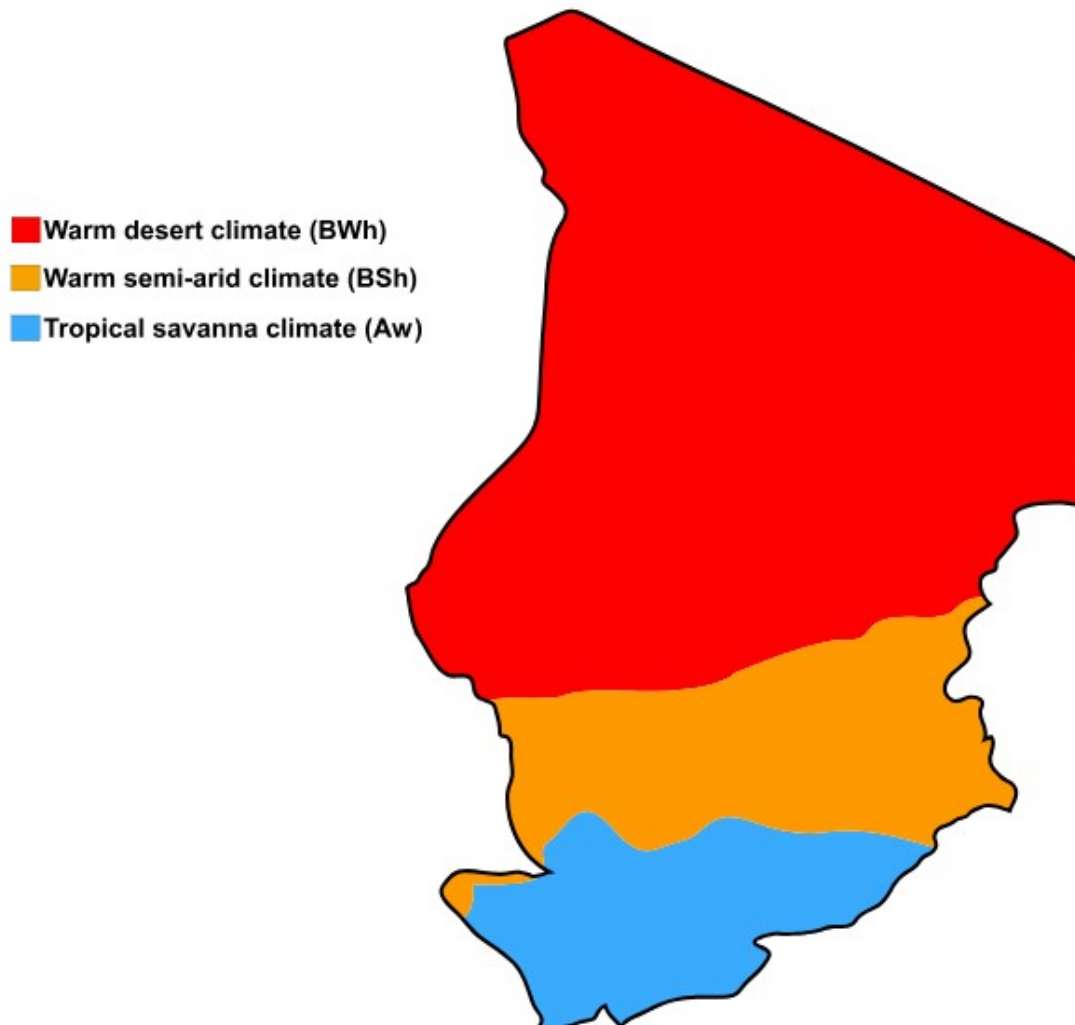
Beginning in the 1970's petroleum was discovered in Chad; first in [Sédigi](#), near [Rig Rig](#), to the north of Lake Chad and later, in the 1980's near [Doba](#) in the southern region of the country. According the [USGS Minerals Yearbook](#), 37,000,000 barrels of petroleum were produced in 2019, 7,000,000 barrels of which were refined at the [N'Djamena refinery](#) and the rest exported.

Other mineral production includes [artisanal gold](#), cement, aggregate, clay, lime, limestone, salt, sand, and crushed stone. Production figures are difficult to obtain for these activities.

Another vital resource in Chad is groundwater, you can find a description of the hydrogeology of Chad [here](#). Briefly, 80% of the groundwater pumped (abstracted) in Chad is used for agriculture, i.e. irrigation and livestock watering; and the remainder is used for domestic consumption. Groundwater also provides a large proportion of water supply in the towns and cities, including the Capital, N'Djamena.

## Climate

Chad map of Köppen climate classification



**Figure 6 – Chad Map of Köppen Climate Classification**

**Credit: Ali Zifan; Creative Commons Attribution-Share Alike 4.0 International license**

More than half of Chad is hot desert ([BWh](#)). South of the desert zone is an area of semi-desert ([BSh](#)) and in the south of Chad is a zone of tropical savanna climate ([Aw](#)). Monsoon rains bring rain to the south from May to early October, with rainfall decreasing as you move north.

If you are interested in travelling to Chad, you may want to visit [this site](#) to check out the climate and [this site](#) to find out that it is not exactly a safe place for casual tourism.

## History and Geopolitics

### *An Ancient Land*

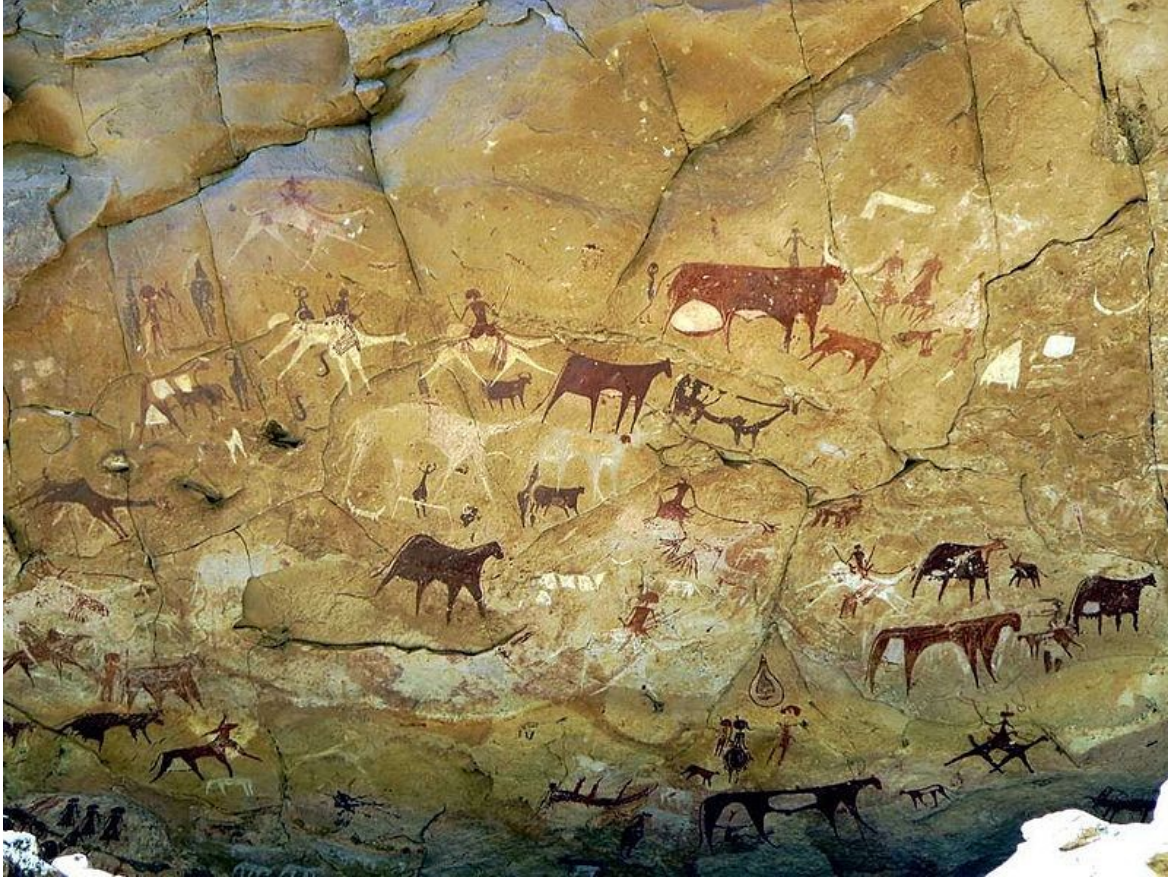


Figure 7 – Prehistoric Rock Paintings at Manda Guéli Cave in the Ennedi Mountains, NE Chad  
Credit: [David Stanley](#), [Creative Commons Attribution 2.0 Generic](#) license

Human and [prehuman presence](#) in the area of modern day Chad goes back to the [Paleolithic](#). During the [African Humid Period](#) that lasted from the [Late Pleistocene](#) to the [Early Holocene](#), the area of the modern Sahara Desert was a verdant grassland, as in Figure 7. Desiccation, [ultimately caused by orbital cycles](#), led to the end of the African Humid Period around 6,000 to 5,000 years ago during the [Piora Oscillation](#) cold period. The people living in the area either migrated or died out.

After about 5,000 years ago, the people living in the region of Lake Chad began adopting agriculture and pastoralism. By 900 AD, state level organizations formed, often by Muslim adventures and warriors spreading the teaching of the [Prophet](#). The first of these states was the [Kanem–Bornu Empire](#) located northeast of Lake Chad and lasting from around 900 AD to 1893. Southeast of the Kanem–Bornu Empire, the [Kingdom of Baguirm](#) lasted from late 15<sup>th</sup> Century AD until 1893. West of Kanem–Bornu, the [Ouaddai Kingdom](#), began during the 16<sup>th</sup> Century AD and persisted until their surrender to [French](#) colonial adventurers in a [war that lasted from 1909 to 1912](#).

The [French began to move](#) into Chad in 1891. By 1898 they had conquered the Kanem–Bornu Empire and the Kingdom of Baguirm. The Ouaddai Kingdom took a bit longer but after 1912 all of modern Chad had

been incorporated into [French Equatorial Africa](#). The French ruled the place until 1960 with the [decolonization](#) process lasting from 1940 to 1960.

Post colonial Chad has not been a happy place; significant events and periods include:

- The rule of [François Tombalbaye](#) from [1960 to 1975](#) ending in [Tombalbaye's assassination](#);
- [Military rule 1975 to 1978](#);
- Civil war from [1965 to 1979](#);
- The [Transitional Government of National Unity](#), and more civil war, 1979 to 1982;9
- The rule of [Hissène Habré](#) from 1982 to 1990;
- [War with Libya](#), 1978 to 1987 including the so-called [Toyota War](#);
- The rule of [Idriss Déby](#) from 1990 to 2021;
- [Civil War](#) from 2005 to 2010 that included conflict with Sudan;
- The death of Idriss Déby ([in battle](#)) in 2021 followed by the establishment of a [military junta](#);
- The establishment of the [current government](#) in 2022.

### *Geopolitics of an Unhappy Place*



**Figure 8 – Chad Police Patrol the Chad-Sudan Border on a [Technical](#)  
Credit: [Henry Wilkins and Arzouma Kompaoré](#) (VOA), [public domain](#)**

Chad has many internal problems: poverty, [malnutrition](#), civil disorder and [outright insurgency](#). These problems might be manageable or even amenable to progressive improvement with an honest government dedicated to improving the lives of their people. Unfortunately, Chad does not have such a benevolent government; on the contrary they have a [corrupt administration](#) marked by [nepotism](#) and [cronyism](#). The prize in much of the internal conflict seems to be access to the wealth generated by the country's oil

production, there's little else worth fighting over in that land. The mechanism for the removal of corrupt leaders in Chad has been by violence and the winners in these struggles help themselves and their military partners to the royalties generated by oil extraction.

Chad's relationships with its neighbours are also difficult. Bad as things might get in Chad, the ongoing conflict in neighbouring Sudan is worse, leading to [thousands of refugees](#) migrating to Chad.

On the other borders:

- There have been armed [border incidents](#) with the Central African Republic;
- Libya [occasionally intervenes](#) in Chadian internal disputes; and
- Chad's neighbour Niger has recently had a [coup d'etat](#).

On top of all this, non-state organizations such as [Boko Haram](#) operate in Chad and it's neighbours, [spreading their version of the Prophet's message through blood and iron](#).

Outside their immediate neighbours, other, more distant, countries have an interest in Chad:

- The former colonial power, France, [has been involved in Chad's internal affairs](#) since independence in 1960 and maintains a [strategic interest](#) in the country along with France's major ally, the [United States](#).
- [Russia](#), through its mercenary company, the [Wagner Group](#), has been [seeking a foothold in Chad](#). This has met with diplomatic push-back by the United States and threatens a [new cold war over the region](#).
- As if American, French and Russian involvement hasn't been enough, [China](#) has been active in Chad, with a Chinese oil company, [PetroChina](#) operating the N'Djamena Oil Refinery; [Chinese relations with Chad](#) go back a long way and the Chinese are credited with [developing the oil resources](#) that fund the Chadian military.

So there you have the story of another unhappy former colony. [Blaming colonialism](#) for the troubles of Chad and other former colonies [is a bit dishonest](#). They have had more than 60 years of independence to sort out their problems and the leadership of Chad bears primary responsibility for the current state of the country. That being said, the people who live there are still in a difficult situation and it is hard to see a happy ending anytime soon for the long suffering people of Chad.

## Standard Caveat

The purpose of my weblog postings is to spark people's curiosity in geology. Don't entirely believe me until you've done your own research and checked the evidence. If I have sparked your curiosity in the subject of this posting, follow up with some of the links provided here. If you want to, go out into the field and examine some rocks on your own with the help of a good field guide. Follow the evidence and make up your own mind.

In science, the only authority is the evidence.