

NIGER

Geography

Niger is a landlocked nation in West Africa and borders the Sahara and sub-Saharan regions. The country is a transitional region between savannah and desert. The Niger River crosses the south-west corner of the country and north-eastwards from it stretches an extensive plateau area, which is mainly desert or semi-desert. In the north of the country, the topography is more accentuated by the Aïr Mountains and the extensions of the Hoggar Mountains from Algeria. The lowest elevation (200 m) is recorded by the Niger River and the highest point is Mont Idoukal-n-Taghès in the Aïr Massif at an elevation of 2022 m. Niger's subtropical climate is mainly very hot and dry. In the extreme south, a tropical climate exists on the edges of the Niger River basin. The terrain comprises predominantly desert plains and sand dunes, with flat to rolling savannah in the south and hills to the north.

Communications are generally difficult and related to the problems incurred by the large expanse of desert terrain. One all-weather road has been built between the coast in Benin and the mining area at Arlit to ensure the supply of mining equipment.

Niger's economy is based largely on subsistence crops, livestock and some of the world's largest uranium deposits. Exploitable deposits of gold are known to exist in the region between the Niger River and the border with Burkina Faso. Substantial deposits of phosphates, coal, iron, limestone and gypsum have also been found. Several oil companies have explored for petroleum since 1992 in the Djado plateau, in north-eastern Niger, and in the Agadem Basin, north of Lake Chad, but to date no discoveries have been worth developing.

Uranium is mined close to the towns of Arlit and Akokan, 900 km north-east of the capital Niamey (more than 1200 km by road), on the southern border of the Sahara Desert and on the western flank of the Aïr Mountains [1].

Geology

Precambrian rocks underlie large parts of Niger (Figure 1), but Cainozoic continental weathering products and sand dunes conceal most of the Precambrian rocks. Paleoproterozoic rocks are exposed west of Niamey, forming a continuation of Birimian rocks from Burkina Faso. Other Precambrian rocks occur in the Aïr Massif in the north of the country. Neoproterozoic rocks crop out south of Niamey along the border with Benin and Burkina Faso, in a continuation of the Volta Basin. Palaeozoic sediments occupy parts of north-eastern Niger and the Agadez Basin west of the Aïr Massif. Cretaceous marine and epicontinental sediments of the Iullemeden Basin occur in central Niger. Volcanic activity, with associated lava, tuff and ash deposition has been recorded from some places intermittently since Devonian times [2].

The broad valley of the Niger River in the south-west of the country lies on a crystalline basement, which, on the eastern bank of the river, dips under sandstones of various ages, which form a plateau sloping towards Lake Chad. A large crystalline massif, the Aïr Massif, is mainly formed by Precambrian gneisses and granites, with some Quaternary lavas, tuffs and ashes. The Aïr Massif separates a number of basins, of which the Agades (or Tim Mersoï) Basin is the most important and is situated near the north-eastern part of the extensive Iullemeden Basin. It is bordered to the east by the Precambrian crystalline rocks of the Aïr Massif and to the north and north-west by the crystalline mass of the Hoggar [3].

Upper Cretaceous rocks and the Cainozoic rocks of the Iullemeden Basin lie to the west and south. To the east of the Aïr Massif, recent sands overlie the Cainozoic sediments of the Tenere, and in the extreme north-east of the country lie the mountains of the Djado (an extension of the Hoggar). The Djado Mountains have a crystalline core and they are surrounded by Carboniferous, Triassic and Lower Cretaceous strata (Continental Intercalaire) similar to those in the Agades Basin, where they host

uranium mineralization. The Agades Basin contains an assemblage of sedimentary clastic rocks, 1000–1500 m in thickness, which were deposited on a relatively stable platform. The rocks range from the Silurian, which rests unconformably on the ancient rock basement, to the Upper Cretaceous. This assemblage is arranged in large sedimentary units, each about 200–300 m in thickness. The region had been occupied by the deltas of large rivers, but intercalated in the succession are marine sequences. The sedimentary assemblage is normally characterized by its grey colour, as typified in the Upper Carboniferous stratigraphic units, corresponding to a fluviodeltaic or marginal marine facies.

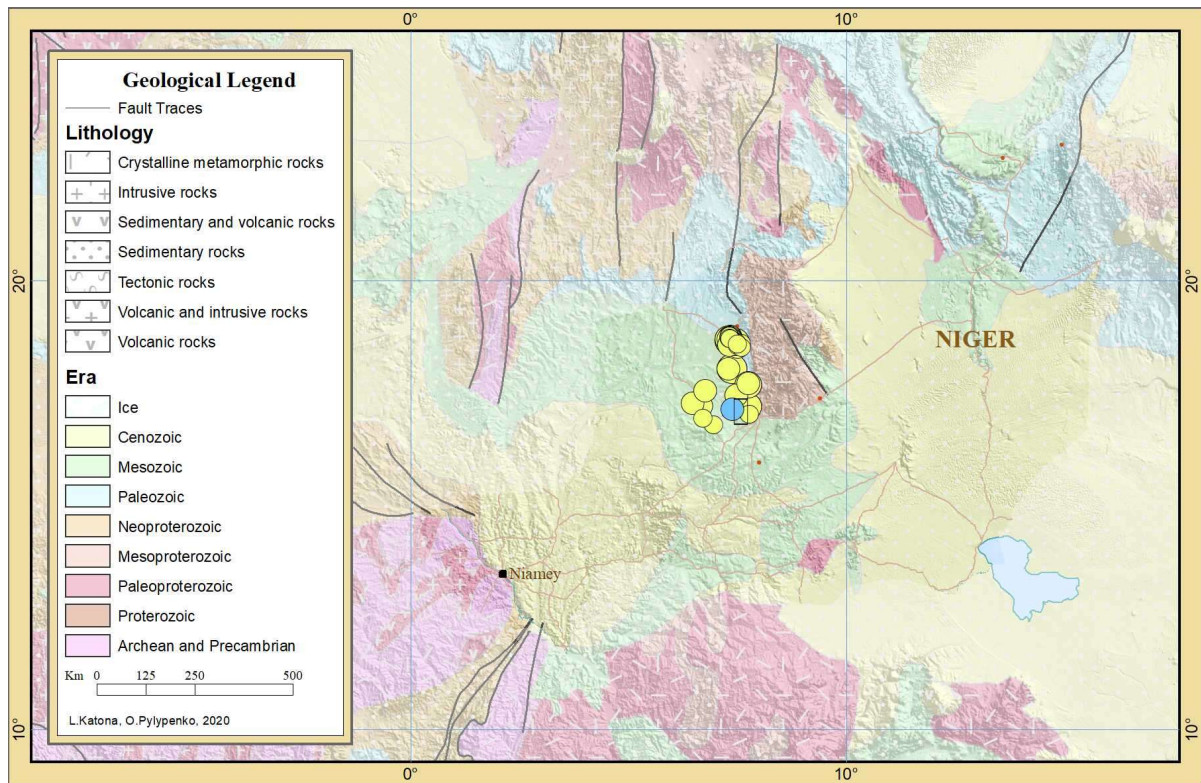


FIG. 1. Regional geological setting of Niger showing the distribution of selected uranium deposits and occurrences. For the general uranium deposit and occurrence legend see *World Uranium Geology, Exploration, Resources and Production*, IAEA, 2020. A general global geological legend is shown although not all geological units necessarily occur on this particular map.

Beginning with the Cenomanian transgression, the colour of the sediments is generally red. The structure of the area is largely inherited from the Precambrian structural alignments. The volcanic activity, which periodically affected the adjacent Precambrian massifs during the Devonian–Jurassic, contributed ash and tuffaceous material, which was laid down contemporaneously with the sediments. Carbonaceous material and coals exist in the sedimentary series and red bed copper mineralization is found.

Niger's main uranium resources are all hosted by the sediments of the Tim Mersoï sub-Basin, which is mainly the continental part of the sedimentary layers of the Iullemeden Basin. The large deposits mined by Compagnie Minière d'Akouta (COMINAK) and Société des Mines de l'Aïr (SOMAÏR) are located, respectively, in the Guezouman conglomeratic formation of Viséan age and in the younger Tarat sandstone formation, which is of Namurian age. Upwards in the sedimentary pile, other mineralization and deposits have been identified, the most important one being the Imouraren deposit located in the Tchirezrine sandstone (Jurassic).

All projections, both laterally and down dip in the Agades Basin, must be regarded as favourable for uranium occurrence. The comparable geology of the Djado region in the extreme north-east must also be considered as being geologically favourable for the discovery of uranium deposits [2–4].

Uranium exploration

Uranium exploration in Niger was initiated by France's Atomic Energy Commission (CEA) and it was followed later (1976) by Compagnie Générale des Matières Nucléaires (COGEMA), which initially concentrated exploration on the granites of the Air Massif. However, by the end of the 1950s, the target had switched to the sedimentary formations of the Tim Mersoï Basin, on the western side of the Air mountain range. Uranium was discovered in sandstone at Abakorum (1959), Madaouela (1963), Arlette, Ariege, Artois, Tassa and Taza, near Arlit (1965), which led to further development work and the formation, in 1968, of SOMAÏR to mine the Arlit deposits.

COMINAK was formed in 1974 to exploit the Akouta deposit and mining started in 1978. Geologically, all of these resources are in deposits of the sedimentary type and hosted in sandstone or continental pelitic formations belonging to the Carboniferous and, to a lesser extent, Jurassic systems (Imouraren).

Exploration was also conducted in the Djado Basin (north-east of Niger), but without success. In subsequent years, both SOMAÏR and COMINAK conducted exploration solely to improve knowledge of existing deposits. SOMAÏR delineated the Taza Nord deposit, while COMINAK evaluated a mineralized area located south-east of the Akola deposit. Exploration activities slowed in 1981 and 1982, and some exploration concessions were cancelled. Work, however, continued within the Imouraren and Afasto–Ouest joint ventures with Niger's Office National des Ressources Minières (ONAREM).

The Imouraren and Afasto–Ouest joint ventures involved COGEMA, Conoco and ONAREM and COGEMA, the Overseas Uranium Resources Development (Japan) and ONAREM, respectively. The Abakorum–Azelik concession was also explored in a joint venture between Japan's International Resources SA and ONAREM. Similarly, the Sekiret concession was a joint venture between Japan's Power Reactor and Nuclear Fuel Development Corporation (PNC) and ONAREM.

The Afasto–Ouest partners presented a feasibility report in March 1982 demonstrating the existence of a deposit of 25 000 tU of reasonably assured resources and 60 000 tU of estimated additional resources (EAR-I). Between 1983 and 1986, exploration concentrated on the Abakorum, Azelik and Sekiret licence areas. At Abakorum, a mineralized zone was discovered by drilling in the upper part of the Madaouela Series, and at Sekiret, close spaced drilling proved the presence of about 4000 tU, with an average grade of 0.11% U, over a thickness of 2.9 m. In 1987 and 1988, exploration activities decreased. Exploration drilling declined progressively from over 23 500 m in 1986 to 10 000 m in 1987, and to 2200 m in 1988. The area held under exploration licence decreased to 5400 km² in 1988, in contrast to 7390 km² in 1987.

Since 1993, both SOMAÏR and COMINAK have carried out significant drilling campaigns. The results of the drilling led to a reassessment of the resource estimates of the Takriza and Tamou deposits by SOMAÏR, as well as further evaluation of the south Akouta and Akola deposits by COMINAK. In 1997 and 1998, SOMAÏR drilled 598 percussion holes, totalling 47 431 m, focusing on the Tamou deposit. A 25 m drill hole spacing was used to delimit the deposit. The limits of mineralization were established to the north and further reconnaissance was undertaken within the adjacent barren cover. To further investigate the Akola deposit, COMINAK drilled 100 holes, totalling 20 659 m. In 1999 and 2000, COMINAK drilled 82 holes totalling 17 854 m to complete the evaluation of the Akola deposit. In 2002, Niger restarted uranium exploration with the Tagora project. This project aimed, in the first phase, to improve the definition of uranium resources near the SOMAÏR and COMINAK mine sites, and in a second phase, to discover additional resources in the region. A resource of 500 tU was discovered in the Tabelle area, and a potential for 16 000 tU was confirmed at the Ebba deposit. On 1 September 2004, the Government of Niger and COGEMA signed a mining agreement to restart exploration. In 2004, a total of 9657 m of drilling was carried out in COGEMA's Arlit concession. In 2004, SOMAÏR continued the development of the Artois deposit, including conduct of a feasibility study, which confirmed a resource of 7921 tU mineable at a grade of 0.30% U, and re-evaluation of the Tabelbelle–Takriza area resource. COMINAK completed development drilling on the Akola deposit. A drilling

programme of 83 holes totalling 20 023 m was carried out on the Afasto concession and mineable resources were estimated at 15 737 tU. A potential 21 172 tU was reconfirmed in the Ebba deposit.

More recent uranium exploration and mine development activities

The revitalization of uranium exploration in Niger began in early 2006, with six new exploration permits granted that year. Among these, the most advanced were the Imouraren exploration permit granted to AREVA NC Niger, and the Teguidda permit granted to the China National Uranium Corporation (CNUC). AREVA NC Niger conducted intensive drilling campaigns on the Imouraren deposit.

Exploration of the Azelik deposits by CNUC started in 2006 and continued in 2007 to confirm the existing resources. SOMAÏR drilling campaigns were conducted to define the north and south extensions of the Tabele deposit. Mine development of the Tamgak deposit started in 2006 and continued in 2007. Further delineation of the southern part of the Ebba deposit was undertaken by COMINAK.

In 2007–2008, activities focused on resource development near the existing mine sites in an effort to expand the resource base in the western Arlit area. Several deposits in this area were also under development (Ebba, Tamgak and Tabele). New exploration and development projects, which included intensive drilling campaigns on the Azelik, Imouraren and Teguidda deposits, continued through 2009 [5–25].

In 2007, GoviEx acquired the Madaouella and Anou Melle permits containing some historical resources discovered in 1963–1965 by the French CEA at Marianne and Marilyn. Between 2008 and 2012, 2391 holes for 189 km were drilled on the Marianne and Marilyn deposits and 4680 holes for 504 km on adjacent areas permitting the discovery of new deposits such as Maryvonne, Miriam and La Banane. In 2013, total compliant resources for 7 deposits were standing at 55 481 t U at an average grade of 0.135% [26]. A mine permit was granted in 2016.

Also, in 2007, Global Atomic Fuels Corp (GAC) had 2 permits granted for exploration, Adrar Emoles 3 and 4, located about 50 km SW of the Imouraren deposit and where uranium was known at Dajj. In 2011, GAC announced the discovery of a new deposit, Dasa. The mineralization is contained in a horst and graben environment with up-thrust blocks. A mineral resource estimation was published in 2013 for the Dasa deposit: 31 955 t U at a grade of 0.132%. The mineral resource estimation was updated in 2017: 43 582 t U, 0.29%. Total geological resources stand at 74 459 t U, at a grade of 0.072% [27].

Figure 2 summarizes historical exploration data for an expenditure total of USD \$831 688 000, including 1 960 049 metres of drilling.

Uranium exploration in Niger was revitalised in 2007. However, since 2011, due to increasing geopolitical tensions in the region, several foreign companies ceased exploration activities in Niger.

GoviEx started a drilling programme in August 2008. Work programme was based on three objectives: i) Resource delineation drilling of Marianne and Marilyn deposits; ii) Exploration and resource definition drilling on the Madaouela South deposit area; and iii) Exploratory drilling between the known deposits. As of February 2010, 584 000 m have been drilled by GoviEx.

Global Atomic Fuels Corp. has six exploration permits located in the north of Agadez, four at Tin Negouran and two at Adrar Emoles. The Adrar Emoles permit hosts the Dasa deposit, a sandstone basal channel type deposit. From 2010 to 2014, Global Atomic had drilled 969 holes for a total of > 120 000 m. In June 2014, Global Atomic announced an internal resource estimate range of 64 600 tU at 0.049 % U (0.0085% U cut-off).

In 2011, URU Metals Limited reported a SAMREC compliant inferred resource of 1 654 tU on the In Gall deposit and continued to drill the Aboye, Akenzigui and Fagochia targets. URU terminated its activities in Niger by 2014.

In December 2010, Paladin completed the takeover of NGM Resources Ltd that held exploration permits in the Agadez region. NGM Resources had announced an inferred mineral resource of 4 320 tU. In early 2011, Paladin carried out a drilling programme that further defined targets for follow-up. However, this was put on hold because of security concerns.

In 2011, GazPromBank Niger Minerals SARL was granted two uranium licences (Toulouk) located in the Tim Mersoï Basin. On March 2017, the company submitted a pre-feasibility study through which it declares according to the JORC code inferred resources in sandstone type tabular mineralisation with 29 630 tU at a grade of 0.0157 %, a roll-front type deposit containing 17 000 tU with a grade varying from 0.04% to 0.06%; and a surficial sandstone type deposit containing 8237 tU at a grade of 0.0252 %.

In 2017–2018, Global Atomic Corporation commenced a new drilling program targeting various parts of the deposit. Fifty-nine holes totalling 26 479 meters were completed. This drill program has successfully delineated higher-grade mineralization within 300 m of the surface. In 2018, Global completed a Preliminary Economic Assessment. Based on this investigation, the most attractive returns would be generated from an underground, high-grade mining scenario which will produce between 1 540 tU and 2 690 tU annually for a period of 15 years [28].

In March 2017, GoviEx started a drilling program (4000 m) focused on expanding shallow near-surface uranium mineralization associated with the Miriam Deposit. The drilling results did not add resources. GoviEx has developed an NI 43-101 Integrated Development Plan for five deposits (Marianne, Marilyn, Miriam, MSNE and Maryvonne). In November 2017, NI 43-101 compliant resources of the Madaouela Uranium Project were 42 603 tU measured and indicated resources and 10 647 tU inferred resources. An open-pit mine and an underground room and pillar mine with conventional processing is expected to produce 1 030 tU/yr over 21 years. Production is expected to begin by 2022. The environmental and social impact assessment was completed in March 2015, and Goviex obtained a mining licence in January 2016. In 2018, GoviEx reviewed the ore process design of the Madaouela project [38.28].

In 2017–2018, Orano, Cominak and Somair continued exploration and development activities within the mines perimeters and in the Arlit concession. Somair drilled 16 240 m in 2017, 8 150m in 2018, and it was planning 11 863m in 2019 [28].

3.38.3. Uranium resources

As of 1 January 2019, total recoverable identified conventional resources for Niger, amounted to 439 388 tU. All uranium deposits in Niger are sandstone-hosted. Tables 1–4 summarize the essential details and the status of the different categories of Niger's uranium resources. The historic variation in resources is shown in Figures 3 and 4.

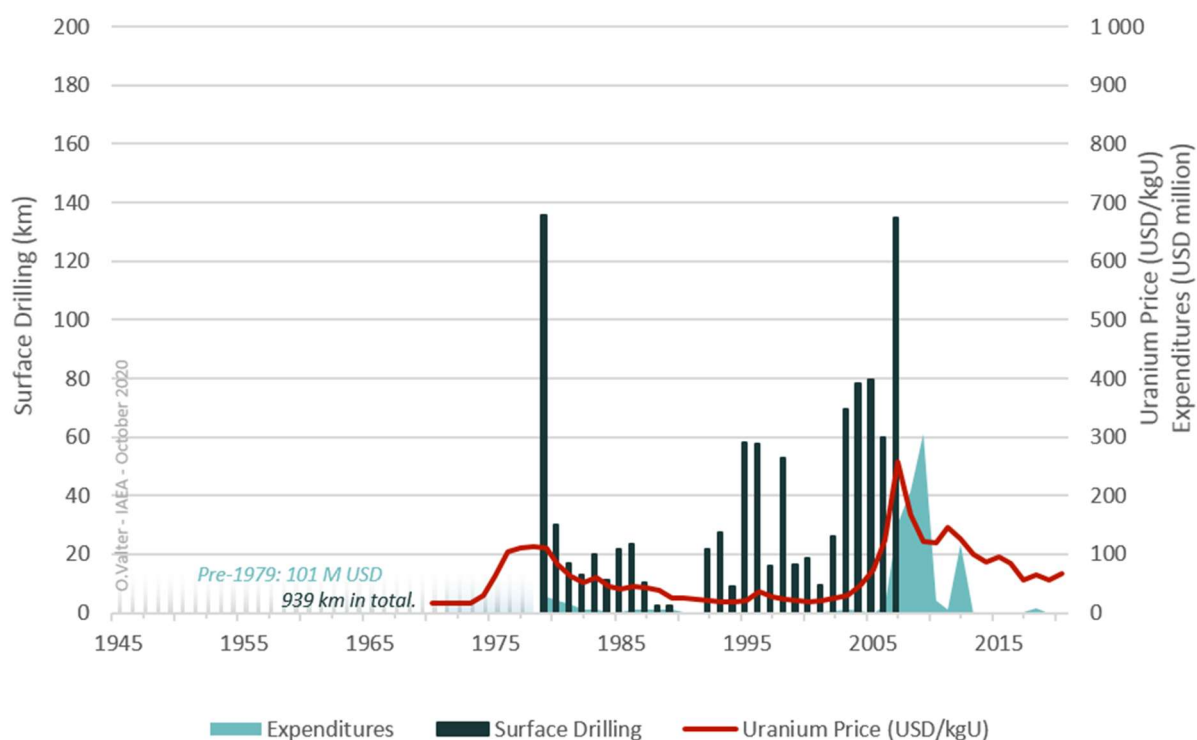


FIG. 2. Domestic uranium exploration data for Niger. Comparison of exploration expenditures, drilling and uranium market price (US\$ current) [38.5–38.28].

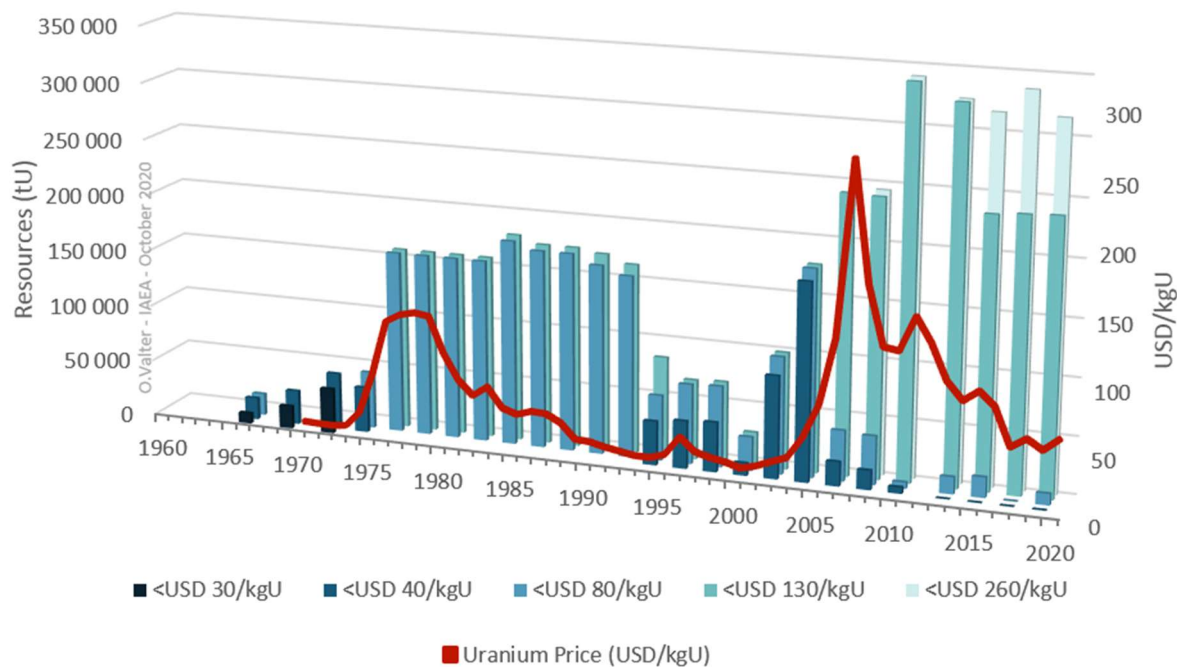


FIG. 3. Historical variation of recoverable reasonably assured resources within various cost categories in Niger. Periods where no resources are shown in any cost categories are periods where resources were not reported, either by the Member State or as a secretariat estimate.

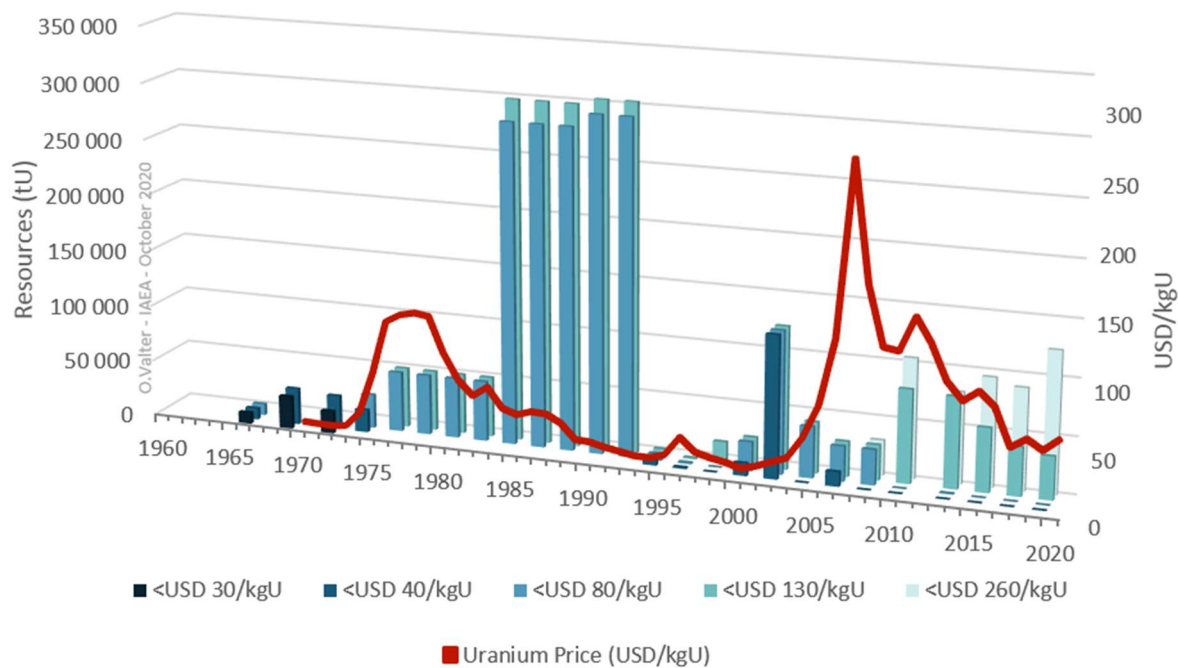


FIG. 4. Historical variation of inferred resources within various cost categories in Niger. Periods where no resources are shown in any cost categories are periods where resources were not reported, either by the Member State or as a secretariat estimate.

Identified resources

TABLE 1. REASONABLY ASSURED RESOURCES BY DEPOSIT TYPE (tU) [28]
(As of 1 January 2019)

Deposit type	<US \$40/kgU	<US \$80/kgU	<US \$130/kgU	<US \$260/kgU
Sandstone	0	9920	238 671	315 477

TABLE 2. INFERRED RESOURCES BY DEPOSIT TYPE (tU) [28]
(As of 1 January 2019)

Deposit type	<US \$40/kgU	<US \$80/kgU	<US \$130/kgU	<US \$260/kgU
Sandstone	0	0	37 733	123 911

Undiscovered resources

TABLE 3. PROGNOSTICATED RESOURCES (tU) [28]

<US \$130/kgU	<US \$260/kgU
13 600	13 600

TABLE 4. SPECULATIVE RESOURCES (tU) [28]

<US \$130/kgU	<US \$260/kgU
0	51 300

Unconventional resources

Niger does not report any unconventional resources.

Potential for new discoveries

The Agades Basin contains the most promising strata for potential additional deposits. Although some exploration work has already been completed, without any significant results, the Djado region in the north-east of the country could also be regarded as favourable. The Djado Mountains, which have a crystalline core, are an extension of the Hoggar and are surrounded by Carboniferous, Triassic and Lower Cretaceous rocks similar to those in the Agades Basin. The area in the south of the country also contains rejuvenated Precambrian rocks surrounded by Cretaceous sediments and these could be worth prospecting. The area to the east of the Aïr Massif also contains Cretaceous and Cainozoic sediments, but these are overlain by recent sands and may be more difficult to explore. The area around Niamey in the south-western corner of Niger contains Palaeozoic platform sediments and Tertiary sediments overlying a Proterozoic mobile belt.

Uranium production

SOMAIËR was formed in 1968 and it commenced production from the Arlette deposit in 1971. Open pit mining of ore grading 0.30–0.35% U was undertaken to a depth of 60 m. Capacity was expanded to about 2100 tU/year in 1981. From 2003, production has been increasing, with the Tamou deposit producing 1565 tU in 2006. In 2009 SOMAIËR started laying the groundwork for a new 1.4 million t/year heap leach operation, while planning for the next deposit, Artois. This deposit is deeper (90 m) and has a lower grade (0.20–0.25% U). Arlette open pit began production in 1968, Ariege in 1976, Taza in 1986, Takriza in 1996 and Tamou in 1998. Through the end of 2017, SOMAIR has already produced more than 70 000 tU.

COMINAK was established in 1974 and it commenced underground mining of the Akouta deposit, close to Akokan. Mining is carried out at a depth of about 250 m. Mill capacity is about 2300 tU/year. Through the end of 2017, COMINAK has produced more than 55 000 tU. Production for 2006 amounted to 1870 tU from ore grading 0.45–0.55% U. Production was switched over to the new deposit of Ebba/Afasto [38.5–38.24].

SOMINA (Société des Mines d’Azelik) was established in 2007 to mine the Azelik and Teguidda deposits by open-pit and underground methods. Production started in 2010 with a projected capacity of 700 tU/yr, but it was suspended in 2015.

SOMAIËR is 63.4% owned by AREVA NC and 36.6% by ONAREM. COMINAK is 34% owned by AREVA NC, 31% by ONAREM, 25% by Japan’s Overseas Uranium Resources Development Co. Ltd and 10% by Spain’s Enusa SA. SOMINA is 33% owned by Sopamin (Niger), 37.2% by CNUC, 24.8% by ZXJOY Invest (China) and 5% by Trend Field Holdings SA.

Historical uranium production is given in Figure 5 and Table 5 summarize the salient production details. In 2019, Niger produced 2878 tU (1750 t SOMAIR and 1128 t COMINAK). Cumulative production was about 146 139 tU to the end of 2019 for the country.

Status of production capability

In 2008, the total production capability was 3800 tU/year, which was in the process of being increased to 4500 tU/year by the construction of a heap-leaching unit. The capacity of the unit will be to process ore at a rate of 1 400 000 t/year from low-grade stockpiles (Table 6).

On October 24, 2019, Orano announced that Cominak will end its uranium production on March 31, 2021 due to the exhaustion of ore and high operating costs [28].

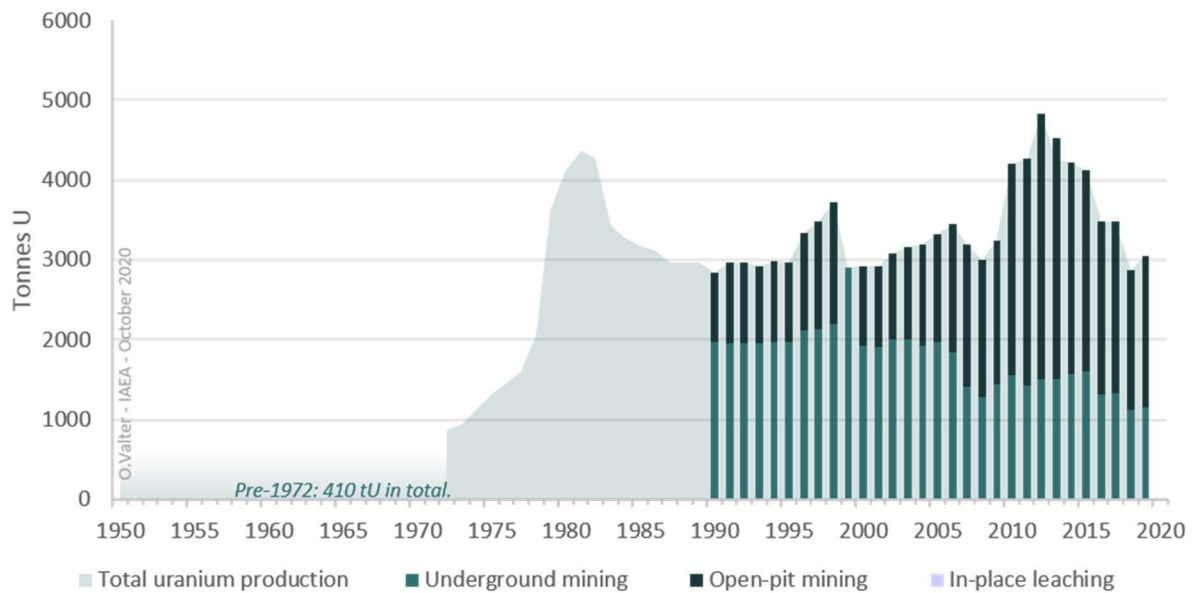


FIG. 5. Historical uranium production in Niger [38.5–38.24].

TABLE 5. URANIUM PRODUCTION TECHNICAL DETAILS [28]

Parameter	SOMAIËR	SOMINA	COMINAK	IMOURAREN
Start-up date	1971	2009	1978	?
Type of ore	Sandstone	Sandstone	Sandstone	Sandstone
Mining type	OP ^a	OP/UG	UG ^b	OP
Resources (tU)	44 626	9684	3538	228 932
Grade (%U)	0.20	0.14	0.31	0.072
Average mining recovery (%)	-	-	-	
Processing plant:				
Type	AL ^c /SX	Alkaline	AL/SX	HP/Acid
Average process recovery (%)	78	85	93	82
Production capacity (tU/year)	1700	700	1800	5000

^a OP: open pit mining. ^b UG: underground mining. ^c AL: acid leaching. ^d SX: solvent exchange. ^e HP: heap leaching.

TABLE 6. SHORT TERM PRODUCTION CAPABILITY (tU/year) [28]
(As of 1 January 2019)

2020				2025			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
		3500	3500	-	-	3500	3500
2030				2035			
A-I	B-I	A-II	B-II	A-I	B-I	A-II	B-II
-	-	5000	5000	— ^a	—	5000	6800

^a —: not available.

Future projects

On 4 May 2009, the Imouraren mine was established, which represented an initial investment of more than US \$1.9 billion. The deposit covers 8 km by 2.5 km and AREVA indicated 213 700 t U reserves at 0.07% U, plus 62 500 tU indicated resources. Orebody depth is between 100 and 150 metres and maximum thickness is 60 m. At full production, the project's acid heap leaching facility will process 20 000 tonnes of ore per day with an expected 85% rate of recovery. The projected mine life when operating at full production capacity of 5000 tU/year is 35 years. Production was scheduled to start in 2013, but in May 2014, with uranium prices not sufficient to justify mining, AREVA decided to put the project into care and maintenance [28].

GoviEx has completed a preliminary feasibility study and planned the construction of an open-pit/underground mine at Madaouela, which could start production after 2022 with a capacity to produce 1 040 tU/yr at the beginning [28].

Global Atomic Fuels plans to construct its first mine at Dasa. It is targeting a 770 tU annual capacity with potential to ramp up to 1 900 tU production per year [28].

Environmental activities

In 2000, both COMINAK and SOMAÏR committed themselves to an environmental management system complying with ISO 14001. They were certified ISO 14001 compliant in 2002. In 2005–2006, three environmental impact assessment studies were completed to gain administrative authorization to mine the Ebba (COMINAK), Artois and Tamgak (SOMAÏR) uranium deposits. At Imouraren, AREVA will spend €6 million annually on health, education and training, as well as providing local people with access to water and energy.

Employment status in the uranium industry

Employment in the uranium industry increased from the start of mining operations in the early 1970s, reaching a maximum of 3935 persons in 2015 with lows during the early 2000s in parallel to the gradual reorganization of the uranium industry from 1990 (Figure 6). The total is 75 677 person-years. Total employment related to existing production centres was 3011 in 2018. Employment directly related to uranium production was 1478 in 2018 [28].

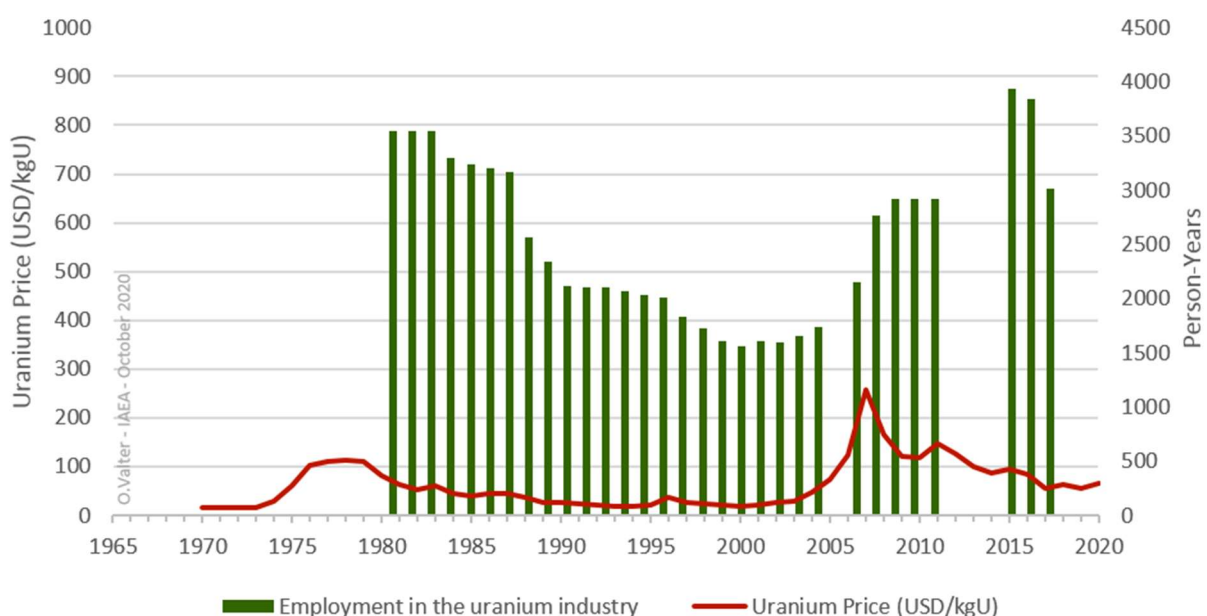


FIG. 6. Historical employment in uranium production in Niger [38.10–38.28].

National policies relating to uranium

One of the main objectives of Niger's national uranium policy is to increase the international competitiveness of its domestic uranium industry.

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