

## GEOHERMAL ENERGY IN THE DEVELOPMENT OF UGANDA

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### **ABSTRACT**

Previous geothermal energy investigations that began in the 1950's have highlighted the importance of the resource as a viable alternative source of energy in Uganda. Studies aimed at evaluating the geothermal potential areas have been undertaken to a limited extent to encourage the development of this sub-sector. However, its development faces constraints that include the monopoly of hydropower in the energy sector. Yet measures have to be put in place to meet the future energy needs of the country, being faced with the fast-growing economy at an average of 6%/year for a decade now. A more serious attempt to articulate the strategic role geothermal energy research and development can play in the economic development of Uganda need to begin now to enhance the development of the sub-sector.

### **INTRODUCTION**

The primary objective of developing the geothermal energy resources of Uganda is to compliment the role of hydro- and other energy resources in the generation of electricity; a crucial element in the development process of the country. Like with the other resources, secondary benefits that accrue from the development of geothermal resources are many. However, the term 'geothermal' is yet to become a catchword in the energy vocabulary of our people. The general feeling is that it is 'exotic' and/or 'ambitious' and so is not a priority. The terms 'Wind', 'Solar' and 'Biomass' energy systems are more familiar to the layman in Uganda than geothermal. Could be that those ones are aggressively marketed or because geothermal, like any other scientific programme, is dogged by those long periods of the 'mysterious' scientific research as opposed to the normally short periods of technological and engineering innovation required to harness the other energy resources. No doubt, hydropower enjoys a monopoly position in the 'energy mix' of the country

as an indigenous resource, the sources of which the country is abundantly endowed with. The onus is on us, the geothermal community, to put forward our case, which is the subject of this paper.

### **ECONOMIC OVERVIEW**

Uganda is one of the world's poorest countries with an annual per capita income of US\$ 330 (World Bank, 1999). This has been brought about through years of political uncertainty and social unrest. However, since 1986 the economy has started to recover with moves to reform institutional bodies and bring about accelerated economic growth and poverty reduction through strong economic and social policies. However, Uganda is not home and dry yet. A continued effort by government in collaboration with external friends is required to propel Uganda to prosperity in the next millennium.

In 1987, the Government introduced its Economic Recovery Program (ERP). As a result of a market-driven, private sector-oriented development strategy and the country's strong natural resource base, the economy has grown by an average of 6.0% since 1987. It was 5.9% in 1989-1991 and 4.1% in 1991/2. It was 10.5% in 1994/95 FY. During 1998/99 financial year alone, GDP grew by a robust 7.8% against a background of instability in foreign exchange markets, problems in the banking sector and low prices for coffee, the main export, on the World Market (Budget Speech, 1999/2000). GDP rates of 6.4, 5.8 and 5.8% in the past three years are still strong rates only comparable to those of China in the world for the decade. Uganda is an active member of the Common Market for Eastern and Southern Africa (COMESA), an economic grouping with a population of about 400 million including Egypt (the latest entrant). At the same time, she is a keen advocate of the resumption of the East African Cooperation (EAC) with a population of about 80 million people. The former EAC was made up of Uganda, Kenya and Tanzania. Rwanda and Burundi

are pursuing membership in earnest and this will bring the population to around 100 million.

### **ELECTRIC POWER IN UGANDA**

Hydropower is the main source of Uganda's electricity supply. The Government of Uganda is presently rehabilitating the existing power generation and distribution installations and is studying ways to meet the increasing energy demand by other indigenous energy resources. As part of this effort, the Government is preparing an Energy Master Plan with the help of the World Bank under the Energy Sector Assistance Management Program (ESMAP). Geothermal energy represents a high priority alternative to hydropower, therefore, findings and recommendations from the geothermal project will be an important input to the Energy Master Plan.

Uganda, a country with a population of about 20 million (1999) has a *per capita* energy consumption of 0.3 toe or 12.72 GJ, which is among the lowest in the world. Few people have access to modern energy supplies such as electricity and petroleum. Uganda remains one of the countries with the lowest *per capita* consumption in this sector, at a mere 0.02 toe or 0.848 GJ (Mugenzi, 1999). The energy consumption rate stands at about 5 million toe/year of which approximately 90% is Biomass (wood, charcoal and agricultural residues).

The total generating capacity of the power system in Uganda is 195 MW only, and the total demand is estimated to be around 580 MW by the year 2005. The major hydroelectric plant is Owen Falls dam (recently re-named Nalubaale) at Jinja with a rated capacity of 180 MW. An extension to this (now Kiira) is currently under construction on the eastern side rated at 200 MW on completion. However, only Units 11 and 12 (40 MW each) totaling 80 MW is on line at the moment. Unit 11 was commissioned on 19<sup>th</sup> May 2000 while Unit 12 was commissioned on 28<sup>th</sup> August 2000, bringing the total generating capacity to 275 MW) (**Table 1**). Unit 13 is still under construction and is due for commissioning by 2002. Unit 14 and 15 are still under negotiation with the financiers (Bidasala, *pers. comm.*). Total continuous power theoretically available from the Victoria Nile is of the order of 2.5 million KW or 22,000 million KWh/year (Gibbs, et al., 1948). The geothermal potential of Uganda was estimated to be 450 MWe (McNitt, 1982).

Given the dismally low power available to a fast growing economy like that of Uganda today, the Uganda Electricity Board (UEB), the state utility responsible for generating and supplying electricity, has adopted what is called 'load shedding'. Load shedding is a technique for rationing the little power

available among the ever-increasing power needs of electricity consumers.

### **ELECTRIC POWER DEVELOPMENT STRATEGY; RESTRUCTURING**

Undoubtedly, Uganda is struggling under an energy crisis. Less than 5% of the population has access to electricity. Demand for power is growing at 3-4 MW a month (18%/year). According to the Ministry of Finance (MoF), the economy loses about 2% of economic growth annually, equivalent to about US\$ 150 million each year due to lack of enough electricity. It is estimated that manufacturing industries lose about 90 days a year of production. This devastating impact on the economy means fewer jobs, fewer people with access to electricity and ultimately a poorer Uganda, environmental degradation notwithstanding. The provision of reliable electricity to the rural areas is also one way of facilitating the private sector, as an engine of growth, to invest in these areas. One of the major reasons why private investors have not invested outside the Kampala-Jinja area is due to lack of reliable power in areas outside this complex. If the private sector is to spread to other areas and therefore bring about balanced growth in the economy, then the need to electrify rural areas cannot be overemphasized. In this regard, Government has indicated willingness to collaborate with any group in the development of energy sources that can quickly come on stream to meet the present and future demand.

At the same time, the electricity export market is still robust. Tanzania is committed to importing 100 MW to supply her Lake Victoria gold mining district. A 66 kV line to Bukoba is already in place with a possible upgrading when the need arises. Rwanda is committed to buying 30 MW once the existing transmission line is upgraded. Likewise, Kenya is yet to commit herself to buying up to 100 MW, up from the current 30 MW it has been importing from Uganda since the 1950's. Owing to the recent devastating drought experienced in Kenya, Uganda has been exporting up to 50 MW as per the existing grid system capacity. This scenario calls for a considerable increase in generating and transmitting capacity over the next 10 years and so far several measures have been put in place by government in this respect.

Table 1. Present and Planned Production of Electricity in Uganda (Adapted from Proceedings of the World Geothermal Congress (WGC) 2000 CD-ROM, Folder 01, 0864.PDF)

|   | Geothermal   |                     | Fossil Fuels |                     | Hydro        |                    | Nuclear      |                    | Other Renewables (specify) |                    | Total        |                    |
|---|--------------|---------------------|--------------|---------------------|--------------|--------------------|--------------|--------------------|----------------------------|--------------------|--------------|--------------------|
|   | Capacity MWe | Gross Prod. GWh /yr | Capacity MWe | Gross Prod. GWh /yr | Capacity MWe | Gross Prod. GWh/yr | Capacity MWe | Gross Prod. GWh/yr | Capacity MWe               | Gross Prod. GWh/yr | Capacity MWe | Gross Prod. GWh/yr |
| In operation in January 2000                                    | -            | -                   | 1.6          | 0.96                | 275.0        | 1445.4             | -            | -                  | -                          | -                  | 276.6        | 1446.36            |
| Under construction in January 2000                              | -            | -                   | 0            | 0                   | 120.0        | 630.72             | -            | -                  | -                          | -                  | 120.0        | 630.72             |
| Funds committed, but not yet under construction in January 2000 | -            | -                   | 0            | 0                   | 0            | 0                  | -            | -                  | -                          | -                  | 0            | 0                  |
| Total projected use by 2005                                     | -            | -                   | 1.6          | 0.96                | 580          | 3048.48            | -            | -                  | -                          | -                  | 581.6        | 3049.44            |

An Energy Bill was tabled before parliament with the main aim to restructure the utility and at the same time pave the way for the introduction of Independent Power Producers (IPPs). Monopolistic rights to future generation opportunities have been rescinded by the new legislation enabling any person or company to enter the power generation and distribution business. The Bill has already been enacted into law (The Electricity Act, 1999) with a provision for setting up an entirely independent Electricity Regulation Authority (ERA). The ERA, comprising of five 5 members is in place already.

In response to the government's proposed liberalization of the energy sector, several IPPs have expressed willingness to invest in power generation in particular. Notably, AES Electric of USA (250 MW), NorPak of Norway (200 MW), both with intentions to develop power along the River Nile have presented their EIA reports. A Power Purchase Agreement (PPA) has been signed between GoU and AES. The latter is now negotiating with the financiers. NorPak is yet to progress in line with the power needs of the country. A new 10 MW facility on the Mubuku River in the Ruwenzori Mountains was recently completed. The bulk of the power from Mubuku is supplying the cobalt plant at Kasese. The Nyagak River project is at the drilling stage. The

latter proposal is being considered seriously under the World Bank-funded Rural Electrification Strategy recently launched by the GoU. The African Development Bank (AfDB) is funding a study to assess all renewable energy resources to establish their potentials. The project will advance those with the largest potential to the level of feasibility studies. All these developments are geared toward stemming out wood usage, which now approximates to 28 billion cm<sup>3</sup> as firewood and charcoal.

#### **GEOTHERMAL RESOURCES EXPLORATION ACTIVITIES; A REVIEW**

The history of geothermal exploration in Uganda is best summarized by Mboijana (1994) in addition to the technical reports for Geothermal Energy Exploration Project I - UGA/92/002 & UGA/92/E01 by the UN. The reports include: An inventory of the three geothermal areas (Gislason, et al., 1994), Geology and Geochemistry studies (Gislason, 1994 and Armannsson, 1993, 1994), Recommendations for Geophysical Studies (Arnason, 1994) and a Geothermal Utilization Study (Matthiasson, 1994). On the whole however, preliminary geological and geochemical investigations of three geothermal fields in the western sector of the East African Rift System indicate all of them to be electrical-grade hydrothermal systems depending on the kind of

technology to be used. Temperatures of 140-200°C, 120-135°C (150°C max.) and 200°C and above for Katwe, Buranga and Kibiro respectively were predicted by geothermometry. The two fields of Buranga and Kibiro are clearly hot-water dominated systems while that of Katwe could easily pass for a vapour-dominated system akin to the Geysers, California using the principle of 'analogy' (McNitt, 1982). The principle uses the knowledge and experience gained in a relatively well-explored region as a basis for extrapolating limited data to a relatively unknown region. By the same principle, Buranga is akin to the Lake Bogoria hot springs of Kenya save for the lack of exposed volcanics in the former case. The Katwe field is characterized by feeble hot springs, warm and cold mineral springs, whereas the Buranga field is characterized by impressive surface manifestations in form of vigorous boiling springs, pools and warm ground and yet geochemistry predicts the lowest temperature. While the two fields of Katwe and Kibiro are amenable to conventional geothermal power producing systems, Buranga is clearly amenable to binary power technology.

### **EXPLORATION STATUS**

Although all the three areas are potential geothermal targets, some more work is required to raise the confidence level of the results especially those of Katwe and Buranga. A selection of one of the three areas for detailed studies is not possible at this stage without carrying out geophysical investigations to ascertain the size and structural characteristics of the geothermal reservoirs, which is the subject of Geothermal Energy Exploration Project (GEEP) IIA. Likewise, the origin, age and flow patterns of the water feeding the geothermal systems is the subject of 'Isotope Hydrology for Exploring Geothermal Resources' - Project UGA/8/003 funded by the International Atomic Energy Agency. The funds committed under this programme amount to US\$ 78,575 only. It is envisaged that the results of the latter project will aid in generating hydro-geochemical models of the geothermal areas and perhaps improve on the accuracy level of the results from Katwe and Buranga. The resulting integrated geothermal model(s) will aid in the siting of the first exploration wells. For cost-effectiveness of the investment, a minimum of 20 MWe geothermal development is targeted at the outset (USDOE, 1998).

However, local legend has it that the earth breathes from somewhere in this part of the world. This is corroborated by the name of one crater, 'Nyindo Zensi' in the area, which means 'earth's noses'. Could this be indicative of a fumarole? This crater lies to the northwest of Lake Kitagata crater. The latter carries the hottest spring at 70.1°C issuing from

beneath the lake. Earlier attempts to locate it proved futile owing to lack of time. Once located, the water ch with the vapour phase interpretation. Unless otherwise, some indication of the hidden treasure beneath the Katwe field is implied from geochemistry where it falls in the steam-heated waters corner on the Giggenbach diagram.

### **GEOTHERMAL ENERGY DEVELOPMENT; RELEVANCE TO OTHER GEOLOGIC STUDIES**

Other than providing specific information about an energy resource, geothermal studies are also relevant to other geologic studies of national concern. Because most geologic processes are ultimately driven by the Earth's internal heat engine, geothermal research contributes to an understanding of such natural phenomena as mineral-deposit formation, earthquakes and volcanic eruptions (Duffield et al., 1994). No where else can this be truer than in this sector of the Rift Valley System as the account below illustrates.

- With respect to the tectonic and geologic setting, this sector of the rift valley and its immediate environs, are hosts to a variety of minerals; economic and uneconomic alike. Base metals (e.g. copper and cobalt at Kilembe), precious metals (gold and silver) on the flanks of the Buhwezu plateau, limestone at Hima, Muhokya and Dura, the mixed salts of Lake Katwe, the gypsum at Kibuku to the north of Buranga, Kanyantete and Muhokya to the north of the Lake Edward - Kazinga Channel - Lake George water system, petroleum shows and diatomite in the Albertine Rift sector, strong indications of Rare Earth Elements (REEs), zeolites, bentonite clays, workable and worked deposits of tin, wolfram, beryl, columbite-tantalite, uranium and diamond traces, in one way or the other, owe their origin to processes involving the circulation of hydrothermal fluids. A good example is a silver-black polymetallic mineral, confirmed to be pyrrhotite ( $Fe_nS_{n+1}$ ), which is issuing at the Kibiro hot springs. Could this be indicative of the classical 'black smokers'? The discovery of gabbro, a Plutonic igneous rock, provides a window of opportunity for the discovery of metallic sulphides (Cu, Fe, Ni, with Pt, Au, Ag and so on.) in the Kibiro area (e.g. Read and Watson, 1985). Any similarities with the Skaergaard Intrusion of East Greenland? This warrants further scientific research.
- Normally, the traditional geothermal energy industry is set within a volcanic environment characterized by calderas, active volcanoes associated with extensive lava flows and pyroclastic material, etc. However, this sector is

unique in that only profuse volcanism, characteristically peralkaline in nature and only limited to nodes where rift strikes intersect or change occurs. The Ruwenzori Mountain Range (120 km × 50 km) is a horst block set in a graben structure on either side. It lies at a double node of structural importance (McConnell, 1972). It is here likened to the Plate Tectonic Setting of the Salton Trough and the associated Cerro Prieto Geothermal Field (CPGF) as in Elders, et al., (1997) except that the lack of spreading of the rifts may be due to the compression of the African Plate between the spreading Mid-Atlantic and Mid-Indian Ocean Ridges (McConnell, 1972). Therefore, the mystery surrounding the CPGF with respect to what lies beneath it could also be true for this sector of the Rift System. For example, apart from the large uncompensated negative Bouguer anomaly in this sector of the rift as opposed to the large positive regional gravity anomaly for the CPGF, similarities occur in anomalous seismic velocities in the deep crust, high heat flow, high seismicity and the occurrence of Quaternary volcanics associated with the geothermal fields (e.g. Maasha, 1974). While these volcanics appear on the surface in Katwe, their presence is indicated, from aeromagnetic data, to occur beneath the other two fields of Buranga and Kibiro (Edcon, Inc., 1984). These facts compare favorably with those at CPGF. Geological evidence indicating the role of magmatism has been deduced from the floats of gabbro and dolerite recently discovered around the hot springs (Isabirye, et al., 2000). They are believed to come from the rift scarp above Kibiro. Likewise, the presence of charnockite intrusions in the vicinity of Kibiro as reported by Simmons (1919), is further evidence of zones where magmatic and metamorphic processes merge. From seismological records, the Ruwenzori region is the most seismically active (Katwe and Buranga), followed by the Toro-Bunyoro fault (Kibiro). The high heat flow is exemplified by the geothermal manifestations in form of hot springs found in each of the areas. Indications of high temperatures involved in the generation of the complex chemistry of the ultramafic xenoliths found in the craters of Katwe underscores the role of the mantle in the sector (e.g. Lloyd, 1985, Lloyd, et al., 1991). However, oceanic crust similar to the Afar Triangle cannot be ruled out (e.g. Duffield, et al., 1997). In my view, it is a 'passive' pull-apart basin perpetually in tension. It is only through geothermal research and development that these theories can be tested and in an economic way too.

- A source of hydrological/hydro-geological information that could be useful in elucidating the probable origin, age and history of development of the Lake Katwe brines by the use of isotopic data. Attempts to utilize these brines for salt production and associated chemicals in the 1970's came to naught because of poor technical decision leading to poor design that overlooked scientific findings about the nature of the brines. The brines were found to be corrosive owing to their gaseous components which included ammonia and hydrogen sulphide. The result was total corrosion of the processing plant from inlet to outlet. Had geothermal research been incorporated in the scientific studies, this problem could have been averted perhaps.
- From the results of Geothermal Energy Exploration Project (GEEP) I, the chemical composition of the thermal waters from Katwe and Buranga shows that the anions of Cl, HCO<sub>3</sub> and SO<sub>4</sub> occur in about equal proportions. This is an unusual composition of geothermal water whose utilization may prove problematic. This was a major concern in the salt project too. However, research elsewhere has indicated that these may be products of shallow processes which alter the chemistry of the hydrothermal fluids as they ascend to the surface (e.g. Truesdell, 1991). Note also that gypsum and limestone are ubiquitous in this sector of the rift. These are being economically exploited at Kibuku (north of Buranga) and at Muhokya and Hima respectively. Isotopic studies could unravel this mystery and therefore the possibility of intercepting more dilute fluids at depth cannot be ruled out; a fact also recognized under GEEP I.
- The possibility of intercepting freshwater lenses in this characteristically saline environment could be made possible through isotope hydrology studies coupled with the deep penetrating geophysical exploration techniques used in the search for geothermal resources. Drilling for domestic water supplies for the communities of Katwe sector of the rift valley by the UNICEF/GoU project in the early 1990's put forth water of inferior quality (brackish) instead. Typical examples are the boreholes around Katunguru, the fishing village astride the Kazinga Channel. Boreholes WDD 5151, 5152 and 5455 have conductivities of 4.9, 3.6 and 4.9 mS/cm respectively. This compares unfavourably with the 0.2 mS/cm for the Channel water. The result has been their abandonment for the 'sweet' water of the Channel. An example is the Svartsengi

Peninsula, SW Iceland. Through geothermal research, a freshwater lens was discovered sandwiched between an advancing seawater front and the geothermal water plume. The Svartsengi Power plant utilizes a brine fluid at 240°C and heat is mined through heat exchangers. The power plant has a combined use of the geothermal resources; producing hot water for space heating and electricity for the communities on this peninsula which includes the NATO base and Keflavik International Airport. The spent fluids are home to the famous 'Blue Lagoon', a popular tourist attraction. A salt plant was utilizing the same brine from geothermal wells. This scenario could be possible at Katwe.

- The results of isotope hydrology and geophysical exploration studies could also pave the way for the revamping of the long shelved proposed Sugar Plantation Project near Chambura Game Reserve, at the foot of the escarpment to the east of Katwe. In 1954, an electrical resistivity survey that was conducted by the Geological Survey of Uganda (GSU) failed to prove sufficient underground water resources to supply an irrigated sugar plantation (Dyke, 1954).
- High CO<sub>2</sub> gas flows are characteristic of this sector of the rift. While borehole WDD 5455 in the Katwe field measures 1000 mg/kg CO<sub>2</sub> and >2000 mg/kg CO<sub>2</sub> for geothermal fluids (Armannsson, 1993), high gas flows have also been noted in the isolated Kichwamba Volcanics near Fort Portal, some 100 km north of Katwe. Small animals (including birds, rodents, lizards, etc.) die by suffocation in crevices owing to the high CO<sub>2</sub> gas flow. This unfortunate scenario could be turned into a money-spinning project through geothermal research and development. This abundant gas could form the basis of a liquid CO<sub>2</sub> industry very useful in the food and beverages industry. A case in point is the Haedarendi CO<sub>2</sub> plant, Grimsnes, South Iceland. While drilling for geothermal energy, the result was more CO<sub>2</sub> instead of water to a ratio of 12:1.

### **COMPARISONS WITH OTHER ENERGY SOURCES**

Although Uganda's electric energy supply industry is skewed in favour of hydropower, the limitations attached to large dams using conventional technology are numerous. Not only do they require huge foreign-sourced funds at once, they always cause social concern for they involve large dammed-up areas. One can say that geothermal power can compete with small hydro and with the most favorable assumption with large hydro (Table 14 in Matthiasson, 1994). More often than not, the areas are prime agricultural lands as in the case of Uganda.

On the other hand, geothermal energy can be developed step by step in response to funds available and energy requirements at the time. Proceeds from the initial investment can then be recouped back into the project for expansion. Issues regarding the environment are well taken care of through technical design and can only follow hydro (with zero emission) in terms of releasing greenhouse gases to the atmosphere, which is the subject of an Environment Impact Assessment (EIA).

Unfortunately, geothermal exploration in the Protected Areas of Queen Elizabeth and Semliki Forest National Parks is on hold by the Uganda Wildlife Authority (UWA) necessitating high-level policy intervention and review for the good of this country.

### **CONCLUSIONS AND RECOMMENDATIONS**

The monopoly of government in the electricity industry has been a key factor in inhibiting the entry of private power generators in the Uganda electricity supply industry. The location of the three geothermal areas fits in perfectly with the government's rural electrification programme. No doubt, the developments taking place in this part of the country (the western axis) call for prudent planning and the availability of cheap power nearby is the key. Kasese, 30 km north of Katwe is already a growth centre courtesy of the mining industry; the strong agricultural base notwithstanding. The proposed US\$ 35 million upgrading of Kasese Airstrip further enhances the viability of investments in this region. It is possible to introduce floriculture in the district just like it is the case with Naivasha, Kenya. The isolated position of Bundibugyo District (home to the Buranga geothermal prospect coupled with the strong agricultural base (including coffee, cocoa, palm oil, etc.), renders the geothermal project a viable investment. The US\$ 60 million IFAD/GoU Vegetable Oil Development Project (VODP) with a Palm Oil sub-component is a good candidate for the direct uses (as process heat) of geothermal energy development. The Kibiro power, on top of feeding the main grid, can be used to open up this part of the country. Fish processing on Lake Albert is the primary candidate, whereas process heat can be employed in the sugar processing plant at Kinyara and tobacco curing in Hoima and Masindi Districts, if proved feasible. Last but not least, the tectonic and geologic setting of these geothermal resources in a feature of scientific importance as the East African Rift System with its associated mineral occurrences make it a suitable candidate for scientific research and in an economic way too. Finally, the failed projects in this sector of the Rift System underscore the need to respect the role scientific research plays as a basis for successful technological and engineering design. It can only be expensive in terms

of time, whereas the price of hasty decisions are high cost, failure and ultimately fatigue, thereby overshadowing the viability of the project in question.

It is, therefore, recommended that government funds the exploration stages of geothermal as a matter of priority since knowledge obtained from this project is crucial in constraining the genetic models of the mineral resources existing in this sector of the Rift. This will go a long way in stimulating private sector participation in their development for the benefit of society. Finally, it has been observed that the Statute governing Protected Areas if left as it is, may end up polarizing development of our natural resources instead. There is therefore an urgent need to review and harmonize such laws in the interest of Society. A cost-benefit analysis of each resource should be carried out before a decision to develop or not to develop is taken. As one Kenyan Minister remarked: Geothermal is here to stay and the sooner we learn how to use it the better for our people.

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