FALEA: AN UNCONFORMITY-TYPE POLYMETALLIC DEPOSIT, MALI, WEST AFRICA

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1. INTRODUCTION

The Falea project contains a polymetallic orebody hosted within the Neoproterozoic portion of the lower Taoudeni Basin, where it overlies a heavily deformed Birimian basement composed of schists and metasediments. The project is located in western Mali, approximately 350 km west of the capital, Bamako, and consists of three exploration permits covering 225 km^2. Of these, the Falea permit covers 75 km^2 and hosts several orebodies with an indicated mineral resource of 6.88 Mt at 0.115% U_3O_8 (0.098% U(6694t U), 0.161% Cu and 73 g/t Ag, and an inferred mineral resource of 8.78 Mt at 0.07% U_3O_8 (0.059% U (5155t U), 0.20% Cu and 17 g/t Ag, using a cut-off grade of 0.03% U_3O_8 (0.025%U)[1].

2. HISTORY

Uranium mineralization was discovered by COGEMA in 1977, having identified the area of southern Mali and adjoining Senegal and Burkina Faso as having potential as early as 1957. COGEMA drilled 86 holes on a nominal 800 m grid over the Falea permit, and a more concentrated 200 m grid on the Central deposit. COGEMA abandoned the project in 1982, at a time of low uranium prices [1]. Delta Exploration obtained the permit in 2006 from the Government of Mali, with Rockgate Capital, a Canadian company, funding the exploration as of 2007 during the uranium resurgence. Delta acquired Rockgate Capital in 2008.

The exploration carried out by Delta/Rockgate started at the known Central deposit and progressed northwards to define the north zone and, ultimately, define the current resource. The companies also carried out hydrological, environmental and social studies [1]. Denison Mines Corporation acquired the project in 2014 and initiated an airborne geophysical survey as well as soil and termite mound sampling. The Falea project was acquired by GoviEx Uranium Inc. (GoviEx) from Denison Mines Corp. on 13 June 2016.

3. GEOLOGY

The project is situated in the Falea–North Guinea–Senegal sedimentary basin, on the southern edge of the western province of the Taoudeni Basin. The Taoudeni Basin is a Neoproterozoic (750 Ma) to Carboniferous, intracratonic basin. The Falea–North Guinea–Senegal basin consists mostly of the sedimentary rocks of ‘Supergroup 1’, which is the lowermost sequence. This group comprises a basal, predominantly fluvial package grading upwards into a series of shallow shelf sandstones and mid-shelf mudstones (total thickness 500–550 m). The Falea–North Guinea–Senegal basin is situated within the West African Craton between the Archaean rocks to the south-east and the Birimian rocks to the north, east and west.

In the Falea region, this lowermost sequence sits unconformably on the Birimian basement. The basal package (approximately 10-30 m thick) consists of conglomerates (VC), the Kania Mudstone with stromatolites (KI), the Kania Sandstone (KS) and the ASK mudstones. The ASK is marine but the VC and KS represent a fluvial sequence of channel and inter-channel sedimentation with a minor marine incursion (KI mudstone plus thin stromatolites). The sedimentary rocks are largely unfolded and sub-horizontal, with a very shallow dip to the west (<10°). The sequence is intruded by Carboniferous dolerite sills up to 80 m thick in places which form cliffs in the area.

The North and Central zones are bisected by a N–S trending reverse fault, the Road Fault. The Road Fault verges to the west and repeats the stratigraphy and the mineralization in the zone proximal to it. The vertical throw is 70 m. The main deposits are spatially associated with this fault. The eastern portions of the Central and North zones have depths of 180–280 m below the plateau, whereas the western blocks lie at depths of 250–350 m. The Bodi Zone is NW of the North zone, but hosts only sporadic U mineralization. The East Zone is located 4 km from the main deposits and is a small area of Cu–U–Ag mineralization, also spatially associated with N–S faulting [1, 2].

4. MINERALIZATION

The Falea deposits consist of four separate zones known as Bodi, Central, North, and East. The North and Central deposits have been intercepted at depths of 180 to 300 m below surface and are the principal deposits. The Bodi, Central, and North zones occur along a 3 km-long, north-south trending mineralized corridor. The East Zone is located approximately 4 km to the east of the Central and North zones. The Falea deposit is interpreted as an unconformity associated polymetallic deposit with associations of uranium, silver and copper.

The mineralization is mainly located within the KS unit and averages 3.6 m in width. It is also present in the VC, KI and at the base of the ASK. Mineralization can be distributed throughout the KS when it is thin (<4 m), but is most commonly seen at the contacts of the KS with VC or KI or at the lower contact with the ASK. The main gangue minerals detected by XRD in the Falea ore are quartz and muscovite/illite. Chamosite, clinochlore, dolomite, calcite and albite are less abundant. Sulfide mineralization consists of argentite (Ag_2S), tennantite $(Cu, Ag, Zn, Fe)_{12}As_4S_{13}$, galena (PbS), sphalerite (ZnS), cobaltite (CoAsS), arsenopyrite (FeAsS) and covellite (CuS), and their presence was confirmed by SEM/EDS analysis. The main uranium mineral is uraninite (pitchblende), but also includes coffinite and brannerite [3]. Uranium is spatially associated with silver in the North deposit, where native silver can be seen in drill core. The copper is low grade but ubiquitous and present in almost every hole drilled. Uraninite often forms rims around chalcopyrite. Copper mineralization is also present at the base of the ASK formation for widths of 1–4 m.

5. DEPOSIT TYPE

The Falea deposit has been previously postulated to represent a combination of two mineralization events. The first event was similar to a sedimentary exhalative (SEDEX) event and the second event was interpreted to be formation of a roll-front deposit, that is, an epigenetic uranium deposit at a redox interface occurring on top of a SEDEX deposit [2].

In 2011, Rockgate reinterpreted the Falea deposit as an unconformity associated uranium deposit, using a polymetallic egress model as the geological model. The unconformity at Falea lies between the Birimian basement and overlying sedimentary sequences. The egress model was applied due to the presence of the Road Fault, which could have introduced fluids into the sandstones. Unconformity associated deposits are high grade concentrations of uranium that are located at or near the unconformity between relatively undeformed quartz-rich sandstone basins and underlying metamorphic basement rocks. The compositional spectrum of unconformity associated uranium deposits can be described in terms of monometallic (simple) and polymetallic (complex) end members on the basis of associated metals. Polymetallic deposits are typically hosted by sandstone and conglomerate, situated at the basement unconformity. Polymetallic ores are characterized by anomalous concentrations of sulfide and arsenide minerals containing significant amounts of nickel, cobalt, lead, zinc and molybdenum. Some deposits also contain elevated concentrations of gold, silver, selenium, and platinum group elements. Deposits with egress halos include both basement hosted and sandstone hosted types, and the alteration ranges between two distinctive end member types: (i) quartz dissolution + illite and (ii) silicified (Q1 + Q2) + later illite–kaolinite–chlorite + dravite [1, 4, 5].

6. WORK COMPLETED AND DISCUSSIONS

A total of 944 drill holes, representing 231 887 m, have been completed over the Falea deposits. Most holes were diamond cored from the surface, with a small amount of reverse circulation pre-collars. Drilling was completed to define the resources, which leaves significant exploration potential outside the main deposit area. Other work completed over the area includes soil surveys for gold over sub-cropping Birimian, as well as soil and termite mound surveys over the Falea deposits. Radon cup surveys and geological mapping along the range fronts, which included scintillometer surveys, were also completed.

Helicopter-borne geophysical data were collected by Rockgate in 2012 and by Denison in 2015. The data included airborne magnetics, TEM and radiometrics. These data were recently remodelled. The structural complexity of the area becomes evident as a series of N–S and conjugate NE–SW and NW–SE trending fault patterns divide the area into what appears to be horsts and grabens, bringing target horizons of the lower Taoudeni and particularly the KS closer to the surface. The thick dolerite unit unfortunately tends to ‘blind’ the EM and deeper magnetic signatures. In some areas, however, the analytical signal strength of the magnetic data, the EM conductivity and the higher U values from the radiometrics can be correlated [6].

Isopach analysis was undertaken in-house on the main deposit and concentrated on the sequence between the base of the ASK unit to the top of Birimian (the unconformity surface) and the thicknesses of KS, VC and KI. The Birimian surface forms a N–S trending palaeochannel just east of the Road Fault. The VC unit is thicker in this channel whereas the KI unit (thin shale) is only well developed east of the channel. Similarly, the KS unit attains greater thicknesses (>6 m) east of the channel. This suggests that the Road Fault was probably a hinge line or small scarp during sedimentation and created a channel for conglomerate deposition whereas channel edge and interchannel areas were dominated by sand and shale during the brief marine incursion of KI. The channel and interchannel areas formed a sedimentary trap for the focus and the precipitation of metals from saline, metal-bearing brines at a later stage. Similarly, the Eastern zone is also spatially associated with a N–S trending structure and has variable VC thickness. The following points are evident from the isopach work:

- There is a clear relationship between the Road Fault and the distribution of the VC conglomerate supporting the fault scarp hypothesis. Using the base of ASK to the top of Birimian, this is the thicker accumulation, just east of the fault (a paleo-low area). In the field, conglomerates next to the fault had some boulder sized rocks;
- The KS sandstone is better developed (thicker) to the east of the fault zone in the palaeo-high area. The VC and KS may represent facies changes, i.e. channel versus interchannel areas;
- The channel relationship is not so clear if sea level is used as a datum. The base of ASK is considered a better datum because it represents the first major marine incursion;
- Grade accumulation spans both high and low areas, with U and Ag mirroring each other and Cu showing higher concentrations to the east;
- Closer examination of the northern zone highlights the strong relationship between a thin KI unit (mudstone and stromatolites) and higher grades of Ag and U. Again, Cu shows a preference for a thicker KI as a preferred trap. The KI unit represents a marine incursion which was clearly only thinly developed once it encountered the paleo-high;
- The relationships in the Central zone are not as clear, although if the KS is too thin then mineralization seems to reduce in tenor and quantity;

— The isopach work highlights the importance of the sedimentology in creating a suitable trap for precipitation of metals from metalliferous brines which were mobilized after basin formation and relate to fluid movement triggered by a later deformation event.

Whereas there has not been any proper analysis of alteration patterns of the hanging wall and footwall rocks at Falea, visual inspection of drill core reveals that the sandstones contain primary quartz, muscovite and minor feldspars. Alteration includes chlorite, sericite/illite and carbonates (calcite and dolomite). Albite and riebeckite have been observed. Apatite, rutile, zircon and anhydrite have also been noted. Hematite staining is common. In the East fault zone, there is abundant hematite staining and silicification which has pervaded both basement and hanging wall units. Bleached zones and hematite staining was observed in the hanging wall package. Chlorite and sometimes hematite were noted in the basement rocks.

The further delineation of the deposits and comparison with large, rich, historic districts overseas may point to considerably larger resources occurring in the area.

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