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# The Formation of Silali Crater (Kenya) As an Extraterrestrial Impact Crater (ETIC)

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**Abstract**

Extraterrestrial impact craters on the earth's surface are formed by the impact of an asteroid, comet or a meteorite on the Earth's surface. Silali basin is a depression that is found to the north of Lake Baringo; around Kapedo town. It is suspected to be an Extra –Terrestrial Impact Crater (ETIC). The mechanisms associated with impact craters are diverse but generally, when a sizable solid body strikes the ground at a high speed, shock waves propagate into the target rocks. At collision speeds of tens of kilometers per second, the initial pressure on the material engulfed by the expanding shockwaves is millions of times the earth's normal atmospheric pressure, which is 10, 300 Newtons per square meter. This can squeeze dense rocks into 1/3 of their normal volume. Stress can then overwhelm target rocks to an extent that they initially begin to flow almost like a fluid. A decompression wave follows the advancing front wave into the compressed rock, allowing the material to move sideways. As more and more of the target rock becomes engulfed in the shock wave, which expands more or less radially from the point of impact, the flow of the target material behind the shock front, is diverted out along the wall of a rapidly expanding cavity created by the decompression wave. The compacted body now vaporized or melted moves outward with the divergent flow and lines the cavity, forming a conical melt sheet. Remote sensing was utilized to map the Silali basin. Satellite images were used to identify the nature of the crater, since most terrestrial impact craters are not identifiable from the surface of the earth. The images provided critical information that was used to map out the morphological aspects of the crater, some of which have long been buried by forces of denudation, together with tectonic and anthropogenic forces. Remote sensing (satellite imagery and ground photography) was supplemented by interviews, observation and sampling of various rock formations.

**Keywords**: Formation, Crater, Extraterrestrial Impact Crater, Asteroid, Comet, Meteorite

## 1. Background Information

Extraterrestrial impact Craters are divided into three categories according to their morphology, namely:

i) Simple Craters

ii) Complex Craters

iii) Basins

Simple craters are relatively small with a smooth bowl shape. In larger craters, though, gravity causes initially steep crater walls to collapse downward and inward, forming a complex structure with a central peak or peak ring and a shallower depth. The diameter at which craters become complex depends on the surface gravity and the heavenly body involved. The greater the gravity the smaller the diameter, that will produce a complex crater. On the earth, the transition diameter of a complex crater is 2 to 4 kilometers, depending on the target rock properties (www.solarviews.com). On the moon, where gravity is low, the transition diameter is 15 to 20 Kilometers.

The peak ring or central peak complex crater is formed as the initial (transient) deep crater floor rebounds from the compression shock of impact. Slumping of the rim further modifies and enlarges the final crater. Complex structures in crystalline target rocks will also contain sheets of impact melt rock, on top of the shocked and fragmented rocks of the crater floor. On the earth's surface, weathering and erosion of the target rocks, quickly alters the surface appearance of the structure, though in some cases, the resistant rocks will stand out as concentric rings/ peak rings within the crater. On the surface of the moon, complex craters are said to be intact till they are destroyed by subsequent impact events.

A basin, on the other hand, is an Extraterrestrial Impact Crater (ETIC) whose diameter is large and with the increasing diameter, a ring of peaks appears within it, transiting the complex crater into a basin. A single interior ring can qualify an ETIC into a basin (Therriault et al., 2002).

**2. Silali Basin's Formation**

According to Dunkley et al. (1993), Silali volcano was formed around 225ka and the caldera (crater or basin) collapsed around 66-62ka. As stated before, Silali basin is a basin within a larger basin (the outer basin) with smaller basins within it. In addition, there seems to have been impacts at different times in the area, the oldest being the one that formed the huge 'outer basin' and probably triggered the formation of a section of the Great Rift Valley, for example the mid graben and the many spectacular geological features within and around it. The 'outer basin' is surrounded by the rugged Arzett hills to the northwest of Kapedo town, towards Tiati. This is the basin in which the Suguta gorge, Suguta River and hot water falls, cross bedding slumps, the shatter cones of Chemolingot and several breccias occur. Different volcanic rocks, prehistoric caves, some of the mentioned smaller craters, several swamps, hot springs, fumeroles and alluvial deposits are also found in this basin.

Previous studies by some scholars who carried out research in Silali basin came up with a proposition that there existed an earlier caldera before the present 'volcanic caldera'. According to Dunkley et al. (1993) the 'break off walls' (stepped walls) of Silali basin, mark the traces of an earlier caldera. The researchers suggested that the 'break off' wall features are not contemporaneous because they relate to different volcanic compositions. According to Williams et al. (1984), were these features indicative of a bonding within an early caldera, then some mechanism of topographic inversion is required. The researchers argued that the caldera wall sections are not an infill to an earlier caldera wall because the Kapedo tuff exposed within the caldera wall and at the base of the western flanks of Silali basin, have identical ages of about 133ka, similar to the Kapedo tuff around it. In this study, the fact that the basin's formation is not clear and that Kapedo tuff is found on the walls of the basin is evidence that some force, other than volcanicity, played a role in the formation of the basin. In fact, the Kapedo tuff found on the crater's wall must have been ejected out of the impact area by the implied impact and pushed over the wall of the basin. This is deduced from the knowledge that, Kapedo tuff is older than some of the crater rock (133ka versus 65ka) and the youngest rock around the basin is about 4-2ka (Dunkley et al., 1993). Extraterrestrial impact, consequently, provides the mechanism of topographic inversion that Williams and his team required pertaining to the formation of Silali basin (Williams et al., 1984).

Silali basin appears to have formed much later than the Great Rift Valley, though the shield upon which it was formed may have formed immediately after the Great Rift Valley, about 400-220ka (Smith et al., 1995). It is, thus, a basin within older volcanic rocks, such as Kapedo tuffs and other older rocks. According to McCall and Hornung (1972), the foundation upon which Silali rests comprises of lower pleistocene and older intermediate/acid volcanics. In fact, Silali basin may have formed as an ETIC, not only on an area of volcanic rock but on a volcanic shield. For this study, Silali basin is an ETIC that formed on a volcanic shield, it formed on a tectonically unstable volcanic ground, as evidenced by the faults that run across Silali basin, in a North-South direction (Plate 1). It would be expected that the faulting in Silali is not only influenced by localized forces, but by regional forces that link up to the Great Rift Valley formation. The map below (Plate 1) of Silali area provides evidence of fractures all around the basin that appear concentric in formation.

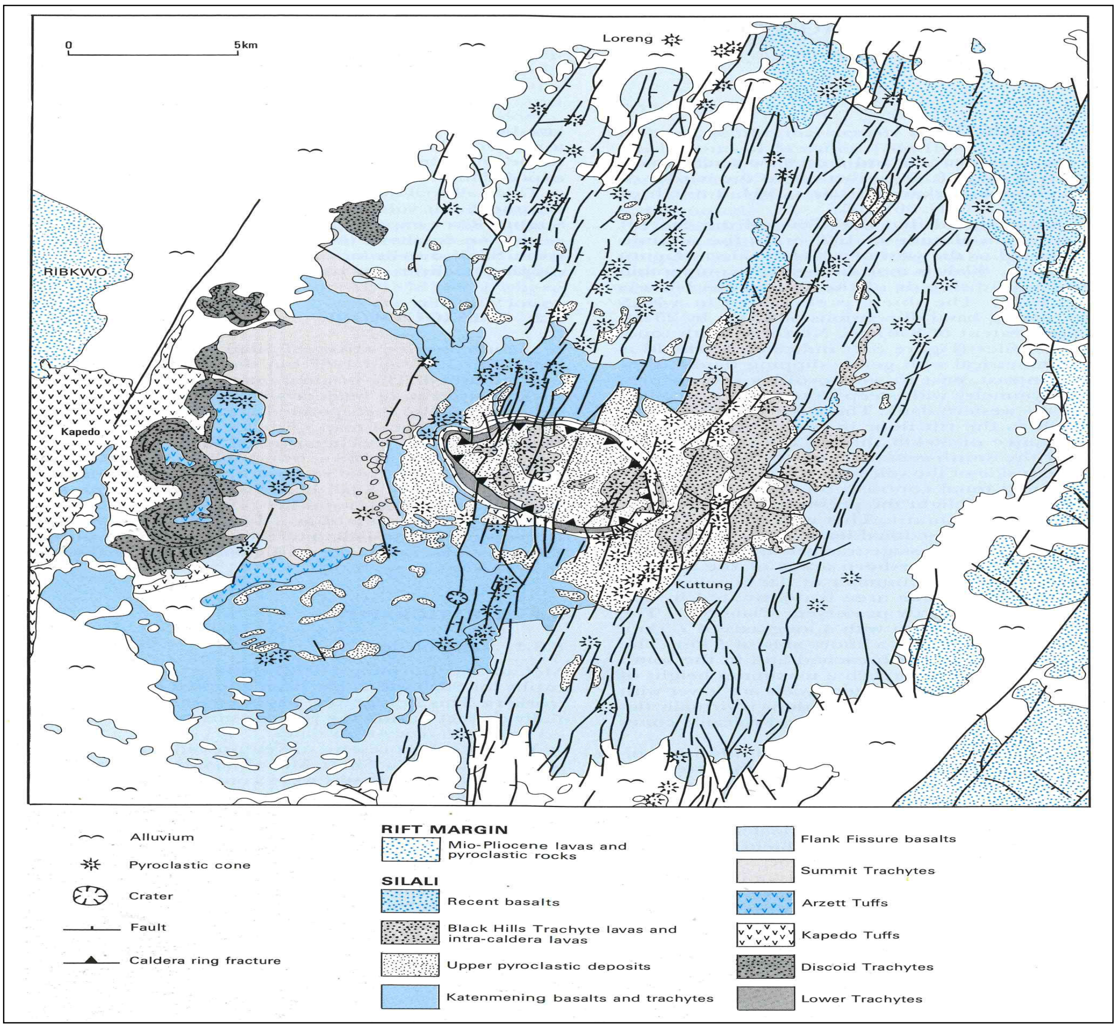



Plate 1: Simplified geological map of Silali basin, showing the basin's ring like structure and the fault lines cutting across the basin (adapted from Dunkley et al., 1993). The dust blanket over Silali basin's wall is also visible on the map.

The formation of the basin may have taken the following stages:

## 2.1 Volcanic shield stage

It is evident that there existed a volcanic shield, in Silali area, that had built over many years by deposition of magma that emanated from a fissure. The shield seems to have been stretching in a north-south direction. According to Smith et al. (1995), Silali's volcano started forming 400-220ka. This included the formation of a low relief lava shield whose summit area was subsequently modified by alternating periods of faulting, subsidence and infilling. Volcanic eruptions in Silali occurred during different times and some of the later ones, according to the authors, resulted in an inward collapse of the shield summit, owing to the lateral drainage of magma from beneath the volcanic shield. These are the eruptions that led to the formation of the caldera around 66-62ka (Smith et al., 1995 and Dunkley et al., 1993).

The existence of a volcanic shield in Silali before the ETIC formed is favored by the following incidences:

a) The fact that Silali basin's wall is made up of volcanic materials placed in layers;

b) The non-contemporaneous nature of the wall materials in terms of age and physical characteristics; and

c) The 'break off' or stepped walls of Silali basin, which evidence layers of different volcanic materials, bearing different strengths against denudation.

It is worthwhile to note that if Silali was a volcano, as purported by available literature, there would be massive lava deposition all around it, which is not the case.

### 2.2 ETIC formation stage

It is possible that, an extraterrestrial object must have fallen on the Silali volcanic shield, impacting it almost at the center. Like all other ETICs, the old Silali ETIC must have been wide, shallow with a well defined gentle rim and low gradient walls that were lined by impact melt (the older caldera). The impact pushed out various broken rock materials. This resulted in the existence of a dust blanket (ejecta) around Silali basin's outer walls, a part of which comprises the Kapedo tuff (133ka). McCall and Hornung (1972) denoted the ejecta as 'an enveloping apron of alluvium' around the 'Silali volcano'.

### 2.3 Subsidence stage

To be able to understand Silali's formation by subsidence, following the impact event, formation of calderas by subsidence should be excursed, as discussed by other scholars.

According to Traver (2007), there are many theories that have been brought forward to explain caldera subsidence. These include:

#### 2.3.1 The crater elevation theory

The crater elevation theory suggests the existence of massive lavas that accumulate on gentle slopes and are later arched to form high cones. The arching might produce wide tension fissures on the flanks of the cones and summit calderas. The theory was discarded after a few years.

#### 2.3.2 The explosion theory

The theory states that large calderas are similar in origin to small craters, the difference being in size. Consequently, calderas form from decapitation of former cones and the deeper the explosion focus, the greater the volume of lithic debris from the sub volcanic basements. This theory was abandoned due to scarcity of such lithic debris in areas of caldera collapses.

#### 2.3.3 The gas -coring theory

Eischer (1929) believed that if a large cylinder was drilled by an explosion, insliding will occur forming a depression that can be many kilometers wide. In fact it has often been observed that slumping of the wall during and after volcanic eruptions, enlarges craters.

#### 2.3.4 Sandberg's 'mantle pipe' theory

This theory held that calderas and craters are formed in the same way. The argument rested on the assumption that the original conduits of volcanic cones are of caldera proportions and that as activity continues to diminish in intensity, the conduits decrease in size and calderas are slowly filled in.

#### 2.3.5 Internal solution theory

According to this theory, volcanoes might enclose a large chamber of liquid lava which might grow larger as a consequence of melting of the chamber walls. As the magma remains inside the chamber, it would crystallize to form a resistant core that can be revealed by erosion. However, if lateral vents drained some of the magma from the chamber, the top solid shell might collapse to produce a caldera.

#### 2.3.6 Wing Easton's cell theory

The theory suggested that volcanic conduits tap magma from the magma chamber. After the first eruption, magma levels fall and gas pressure accumulates in the overlying space, till magma is again forced out. The process is repeated and a high cone is formed at the expense of a diminishing magma chamber. When the magma level falls below a certain threshold, the volcanic cone conduit is plugged by solid lava. The gas in the magma chamber is forced to escape through scattered fissures in the roof. The fissures widen and release magma that flows down the cone slopes. Finally, the upper part of the cone will be too heavy for the small magma chamber, hence collapses to form a caldera.

#### 2.3.7 Collapse theories involving withdrawal of magmatic support

The theory stated that caldera collapse occurs due to the removal of magmatic support occasioned mainly by withdrawal of magma to the surface and injection of deep seated dykes. The removal of magma from a volcanic chamber leads to crustal subsidence and production of calderas.

These theories suggest the existence of an active volcanic vent which does not exist in Silali basin.

As a volcanic shield, caldera formation by subsidence involving a volcanic pipe is not plausible. This is because subsidence would not be a quiet event and an explosion would most likely occur, pouring out magma onto Silali walls. One would then expect Silali to exhibit magma outpourings from its ring structure onto its flanks. This is not the case. Again, the collapse would not produce a perfectly ring structure unless there was an outline of a ring structure in existence.

Caldera subsidence occurs in various ways, such as through plate / piston subsidence, trap door subsidence, chaotic subsidence and down sag subsidence, among others. Plate or piston subsidence involves the subsidence of a coherent block of rock into a magma chamber that evacuates magma along a ring fault. The caldera floor may be variably faulted but the faults are less active than the ring faults (Traver, 2007). Trap door subsidence on the other hand, is subsidence that involves multiple collapse centers. It is piecemeal subsidence. As for chaotic subsidence, wholesale disruption and brecciation of caldera floor rocks is involved. This generates low density materials which cause a caldera to register a low gravity signature. Finally, downsag subsidence occurs when ring faults either do not form or do not penetrate the ground surface so that summit material subsides by bending downwards.

Silali's subsidence may be said to be a plate or piston type of subsidence because the rock layers forming the basin's walls show continuous uniformity in material type and height. This is supported by observations made by Dunkley and team, that; the caldera has a regular outline and vertical walls suggesting that it was formed by a piston like collapse (Dunkley et al., 1993). Unlike in the case of volcanic calderas, Silali's ring fracture was less active compared to the floor fractures, in magma emission. It is thus the crater floor fractures that evacuated most of the magma that may have been beneath the volcanic shield on which Silali basin was build. The lava flow to the northeast of Silali basin can be evidence of such an event. This is because it appears that the magma jetted off the base of the basin's wall. Notably the floor fractures of the basin extend outwards from the basin and not otherwise. The subsidence can also be termed chaotic because of the presence of brecciated rock on Silali's floor and walls. A more apt subsidence theory for Silali basin is any theory that involves withdrawal of magmatic support hence collapse. All the theories mentioned above, entail the existence of a volcanic cone and presumably, a vent/ pipe/conduit. Silali's formation, as a volcanic shield or an ETIC, lacks these two and according to McCall and Hornung (1972), Silali volcano was built by clustered vents (not a central single vent or a volcanic pipe). An extraterrestrial impact, consequently, provides a variable explanation on how Silali developed a crater, via impact and consequent subsidence.

Silali's subsidence can be said to be the factor behind the basin's stepped or 'break off' walls, because as subsidence occurred, the more resistant rocks of the basin's wall remained standing while the softer parts collapsed and later got washed away by denudation. Denudation removed the softer rocks that made up the initial walls of the volcanic shield, forming scalloped areas, while resistant rocks, such as the young volcanic rocks making up the top most layer of Silali basin's wall, remained intact, forming the wall's protruding parts. There is a lot of evidence along the basin's wall, supporting subsidence and especially block/piston/plate subsidence. These include;

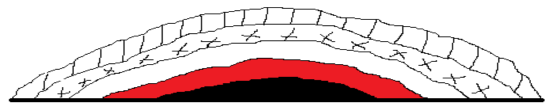
a) The layers that make up Silali basin's wall are almost uniform and continuous around the basin and at the same height from the basin's floor (about 300m).

b) The walls appear to have collapsed inwards, towards the basin. There is an appearance of 'turning inwards' on Silali basin's inner walls, which is different from the 'turning outwards' appearance of the basin's outer walls. Slumping has modified the appearance of the basins inner walls, giving the walls a concave form.

Subsidence was possible for Silali basin because, after the impact, fractures formed around the basin, encouraged by pre-existing rock weaknesses. The impact must have also widened the existing rock cracks, triggering the exit of magma from within the shield's magma chamber onto the areas around the basin. This should have formed some amount of emptiness beneath the impact basin, bringing about a collapse that left high stepped walls. There is evidence (in the form of brecciated and metamorphosed rocks on the crater walls) that hot gases and liquids hissed out of the crater chamber through the many fractures surrounding the crater. From the ground photographs of the basin, presented in this paper, one can clearly see volcanic cones on the western walls of the basin. These were built by magma that outpoured from the impact area, forming part of the evidence of subsidence in Silali.

The following simplified diagrams explain the formation of Silali basin, especially the volcanic shield and impact stages.

(i)



(ii)

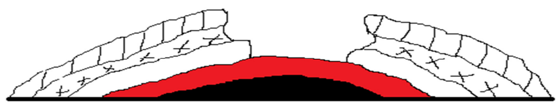


Figure 1. (i) (ii) Diagrams Showing the Formation of the Silali Basin

Figure 1 (i) represents the pre-impact volcanic shield. The shield is made up of different layers of volcanic rock. Figure 1(ii), on the other hand, represents the post impact volcanic shield. As mentioned before, an extraterrestrial impact could have created a crater at the center or near center area of the volcanic shield, opening up the volcanic shield to agents of erosion and weathering. These land remodeling processes caused the softer rocks of the basin's wall to be washed away, forming indented sections. The more resistant rocks, however, remained standing hence forming the protruding areas of Silali wall. Consequently, the basin's wall developed a stepped appearance.

The LIDAR image below (Plate 2) shows fractures that are found within and around Silali basin. These fractures are quite evident on the outside walls of Silali basin where one can feel the hollowness of the ground when one taps the ground with a stick. Plate 3 shows one of the volcanic cones outside the basin and Plate 4 shows the volcanic material making up the top most layer of Silali basin's wall, which may be consisting of shatter cones.

It is not possible to explicitly demonstrate the dynamics that led to the formation of Silali basin because direct evidence has long been covered up by sediments or distorted and changed by neotectonics. Some of Silali's distal ejecta and melt rock, for instance, may have been buried by lava and sediments.

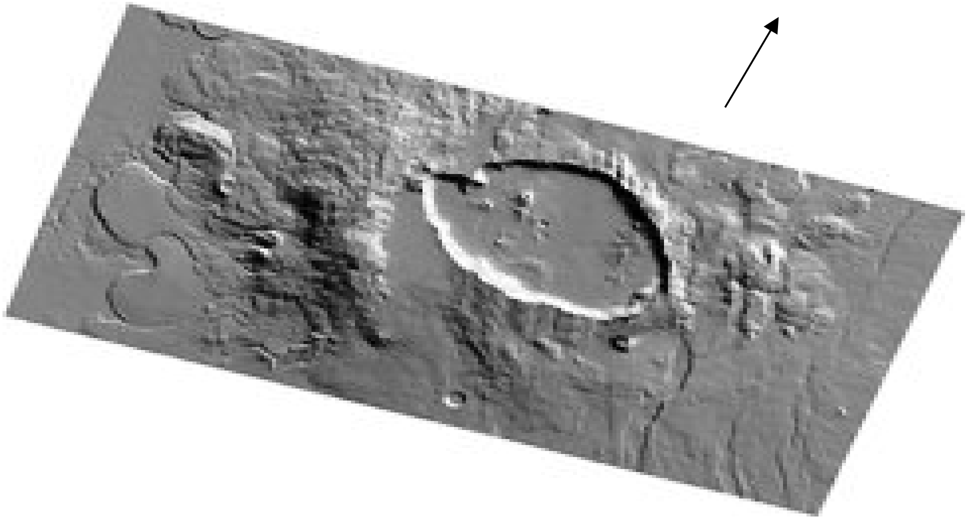


Plate 2: A LIDAR image showing the crater and the fault lines within and around it. The black arrow points to the north (image acquired from GDC library).

The LIDAR image displays many aspects of the basin, besides the shape and the fault lines. It shows some of the faults that have been filled up by magma to create ridges, as evident inside the basin. An outline of the peak ring of the crater can also be deduced from the image, though broken to the north. Volcanic cones and craters inside and outside the basin are also visible.

Plate 3: A volcanic cone to the southern part of Silali basin

The volcanic cone on plate 3 has been heavily weathered, an expression of its old age. The cone falls on the eastern fault line of the basin, in line with the ridge on the eastern side of the basin as can be seen from plate 2.

Plate 4: A photograph showing the top most layer (most recent rock layer) of Silali basin's wall.

The rock layer (dark) shown on plate 4 is of volcanic origin and is visible more on the inside of the basin. On the outside, it is buried by dust, as it sits right beneath the rim of Silali basin. It appears to be made up of massive shatter cones and is continuous all around the basin at an almost uniform height. The rock is also undergoing heavy weathering, which has made it more rugged as parts of it are chipped off. Several blocks of rock, from this rock layer, are found scattered along the wall of the basin, with a few on the basin's floor. They form a part of the heavily fractured rock (pseudotachylites) on the Silali basin's wall, both inside and outside.

## 3. Materials and Methods

### 3.1 Remote Sensing

Although remotely sensed images cannot adequately replace the usual sources of information concerning the environment, they can provide valuable supplements to the field data, by revealing broad scale patterns that are not easily recognizable on the surface.

Many ETICs are not visible on the earth's surface. In addition, a large proportion of them are quite old so that there may be no remaining human beings alive today to recount their formation in comparison to recent events. In addition, their deformation by physical processes such as erosion and other geological events can interfere with evidence of their formation and the formation of related features, making them hard to recognize on the earth's surface.

This study uses remote sensing, which includes satellite imagery and ground photography to reveal details about the Silali basin, for instance its size, shape and associated features as well as identify the general topography of the area where Silali crater is found and the alignment of rock formations in the area. Natural and false colour satellite images (Landsat, SPOT, GeoEye and ASTER images) were important and useful in this study because of their high resolution and clarity in the appearance of the features on the earth's surface.

Hand taken ground photographs of features around and within the Silali basin were also acquired. First, these were a means of data collection but were used to record and present whatever information was collected. A substantial number of ground photographs form a crucial part of this study, as sources of evidence regarding the formation of the Silali basin and the basin's ETIC characteristics.

### 3.2 Interviews

Qualitative research interview was used to obtain the understanding of the people, living in the proximity, about Silali basin's existence and any folklore that has been passed on through generations with regard to its formation. The area residents clearly described the geographical factors operating within and around the Silali basin, such as the operation of the hot water falls, the existence of warm grounds (fumeroles) in the basin and the life of the Pokot families that live within the crater.

### 3.3 Observation

The author visited the Silali area, to collect samples and observe the nature of the basin, its environs and associated features. The observation that was done in this study was mostly non- participatory. Photographs of the rock samples, rock formations in the study area and associated features were taken.

3.4 Sampling

The study adopted probability sampling. Samples that were collected from the field include:-

- Rocks collected within and around the basin.
- Soil samples.
- Other specimens that were of interest, such as fragments of obsidian rocks found around the basin.

Samples were also collected from the area outside the basin (the outer basin) as well as the Silali basin or crater itself.

3.5 Use of Geophysics

Geophysics was used to determine the gravity signatures of the Silali basin and to ascertain whether the basin is actually an ETIC. ETICs are expected to register low gravity readings due to brecciation and target rock fracturing and shattering (Pillington and Grieve, 1992).

Besides the Basin's gravity signature, the magnetic signature, seismic signature and the electric signature of Silali basin were also investigated, because they are all part of the geophysics of the crater.

Due to the fact that geophysical data is very expensive to acquire, secondary data sources were relied on. Consequently, Silali basin's geophysical data was deduced from a geophysical study of the area that was carried out by (Lichoro, 2013).

**4. Results and Discussion**

Laboratory tests carried out on rock samples collected from the study area, a known meteorite (Kimwiri Meteorite) and a suspect meteorite (the Chemolingot rock) yielded the results contained in the graphs below (figures 2- 4).

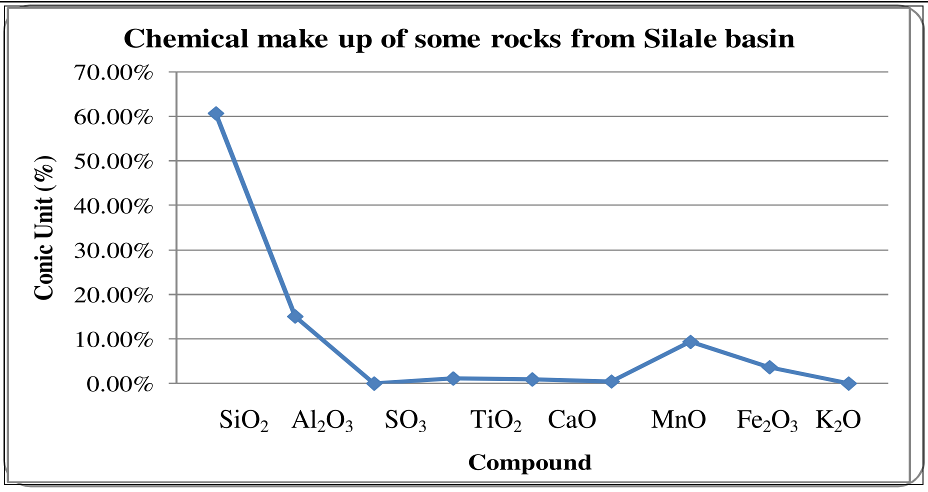



Figure 2. Chemical Make-Up of Some of the Rocks from Silali Basin

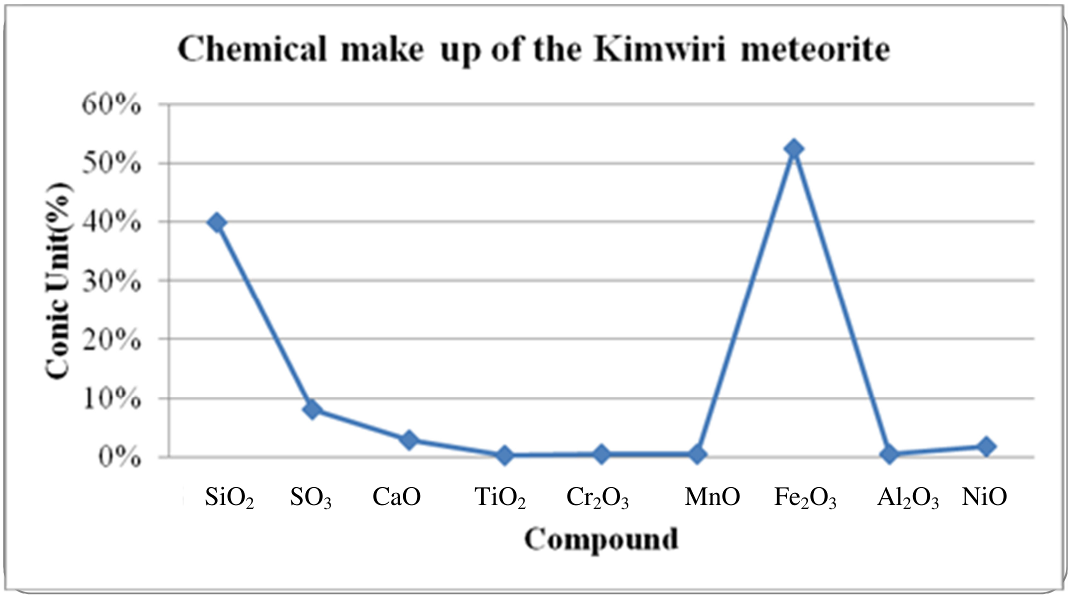



Figure 3. Chemical Make Up of the Kimwiri Meteorite.

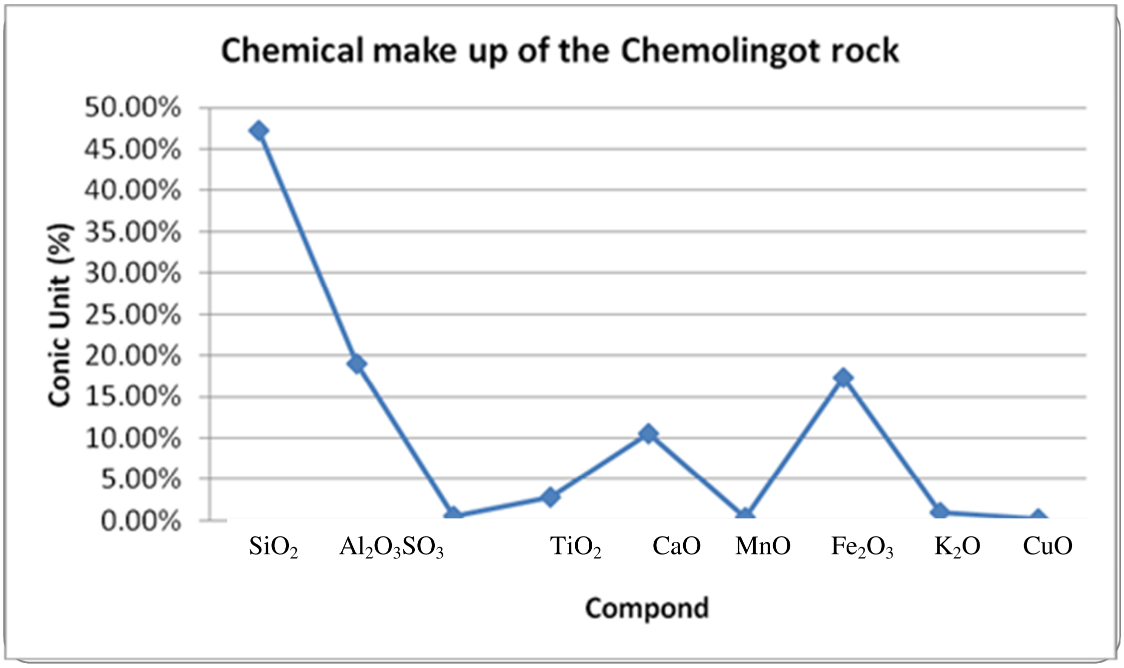



Figure 4. Chemical Makeup of the Chemolingot Rock.

The chemical composition of rocks from the Silali basin was varied as summarized in figure 2. Using a percentage average, the rocks comprised of 60.64% $SiO_2$, 15.05% $Al_2O_3$, 9.35% $Fe_2O_3$ and 3.67% $K_2O$. This showed that the rocks from the Silali basin comprised of a higher proportion of $SiO_2$, followed by $Al_2O_3$ and $Fe_2O_3$, almost like the Chemolingot rock. A similarity with the Kimwiri meteorite is in the higher percentages of $SiO_2$ and $Fe_2O_3$. The results are indicative of Silali basin having volcanic origins as well as being an ETIC. The

Chemolingot rock was collected near Chemolingot area of Baringo East, on the ‘outside basin’. It is suspected to be an achondrite meteorite and appears as shown on plate 5 below. Like the Kimwiri meteorite it has a high $SiO_2$ content.


Plate 5: A photograph showing a unique rock (Chemolingot rock) collected from Chemolingot area, in East Pokot. A brown coated chondrule is pointed by a black arrow.

This study is in agreement with previous studies, especially pertaining to the existence of an old volcanic shield on Silali and crater subsidence. The point of divergence is on the crater formation process and the origin of the grid faults found within the precincts of the basin. For all the earlier scholars, Silali crater is a volcanic crater that was formed by alternate periods of faulting, subsidence and infilling that is associated with volcanic activity (Dunkley et al., 1993). According to McCall and Hornung (1972), Silali volcano was built by clustered vents and not a central pipe. From the book on the Geology of the Maralal area G.O.K (1987), Silali is a composite volcano; a dome built by clustered vents through a first phase of quiet trachyte effusion, followed by emission of trachyte pyroclasts and a return of quiet effusion. Later, the shield suffered some sagging in which a fine grid of normal faults developed, following the extensive emissions of thin basalt from many small vents situated along these fracture lines (G.O.K, 1987). From this explanation, one would expect multiple centers of rock layers making up Silali basin’s wall. As it is, the basin’s walls have continuous layers of different volcanic rocks which are neither of the same age nor composition. This alone, shows that Silali volcanic shield existed and it was not built by a cluster of vents but by a central fissure and probably a few parasitic fissures that build the old cones on the western walls of the Silali basin. The book does not state whether the fine grid of normal faults are on the floor of the crater or on the walls, where Silali basin’s ring fracture is evident. If they are on Silali’s walls, then it would be expected that lava would build up the outer walls of Silali basin, which is not the case. If they were on the crater’s floor, it would mean that the basin’s floor would consist of a network of crisscrossing ridges or fault lines, which is neither the case because the floor has cones, craters and two huge ridges running across its floor. Consequently, while the book attributes the formation of the grid faults to subsidence, the research pegs their existence on rock fracturing following an extraterrestrial impact. The study does not support the existence of a central pipe in Silali basin but suggests the existence of a central fissure with minimal branches. More so, for the research, there was no major volcanic eruption in Silali to create the 5-8 kilometers caldera. Instead, a volcanic shield was hit by an extraterrestrial object that blasted a huge hole on it (crater) and enhanced fracturing in the area. The impact created a ring of fractures which did not emit magma. In time, following an active mantle plume, magma was fired out of Silali basin's floor, through fractures that existed on the basin's floor. This caused the basin's subsidence. The ring fracture of Silali basin, thus, was not active in emitting magma out of the basin's floor. Currently, Silali basin is experiencing quiet volcanicity, which may be attributed to the active mantle plume or magma chamber beneath the basin.

## 5. Conclusion

From afore discussions, Silali basin's formation is via three processes: Volcanicity, extraterrestrial impact and subsidence. Support for these processes comes from previous studies that have been carried out in Silali area (especially for volcanicity and subsidence) and Silali's ETIC evidences that have been presented in this study, as collected and observed in the field.

## 6. Recommendation

There is need for Silali basin's more detailed scientific and gravity mapping for a better understanding of the basin. For gravity data, for instance, the existing data is too sparse to give a detailed picture of localized anomalies (Mariita, 2003).

## References

Dunkley, P. N., Smith, M., Allen, D. J., & Darling, W. G. (1993). Geothermal Activity of the Northern Sector of the Kenya Rift Valley, British Geological Survey, Keyworth: Nottingham.

Escher, B. G. (1929). Formation of Calderas. Leidsche Geologische Mededelingen. Netherlands.

G.o.K (1987). Geology of the Maralal Area, Report 105, Ministry of Environment and Natural Resources. Nairobi.

Lichoro, C. M. (2013). Multidimensional Interpretation of Electromagnetic Data from Silali Geothermal field in Kenya: Comparison between 1-D, 2-D and 3-D MT Inversion. University of Iceland.

Mariita, N.O., & Keller, G. R. (2007). An Integrated Geophysical Study of the Northern Kenya Rift. J AfrEarth Sc, 48, 80-94.

Mc Call, G. J. H., & Hornung, G. (1972). A Geochemical Study of Silali Volcano, Kenya, with Special Reference to the Origin of the Intermediate –Acid Eruptives of the Central Rift Valley. Tectonophys, 15, 97-113.

Pillington, M., & Grieve, R. A. F. (1992). The Geophysical Signature of Terrestrial Impact Craters, Reviews of Geophysics, May, 1992, Vol. 30.

Smith, M., Dunkley, P. N., Deino, A., William, L. A. J., & McCall, G. J. H. (1995). Geochronology, Stratigraphy and Structural Evolution of Silali Volcano, Gregory Rift, Kenya. British Geological Survey, Edinburgh: UK.

Therriault, A. M., Grieve, R. A. F., & Pillington, M. (2002). The Recognition of Terrestrial Impact Structures.Bulletin of the Czech Geological Survey, 77 4, 253-263.

Traver, G. A. (2007). Dynamics and Structural Evolution of Collapse of Calderas: A Comparison between Field Evidence, Analogue and Mathematical Models, University of Barcelona, Barcelona.

Williams, L. A. J., MacDonald, R., & Chapman, G. R. (1984). Late Quaternary Caldera Volcanoes of the Kenya Rift. Journal of Geophysical Research, 89, B10, 8553-8570.