[Siddig, 2(8): August, 2013]

ISSN: 2277-9655
Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Geology and Geochemical Exploration for Gold at Qeissan County, Blue Nile State, S-E Sudan

Siddig, M. Elzien[*1], **Ahmed Haron ElTom**[2]

[*1]Alneelain University, Faculty of Petroleum and Minerals

[2] Ministry of Minerals, Geological Research Authority of the Sudan, Mineral Resources Administration, Khartoum

siddigzien@yahoo.com

Abstract

A Study of the geology and geochemical evolution of the basement rocks of the Blue Nile area shows that they can be placed into five tectonic terrains; amphibolite inclusions unconformably overlain by heterogeneous and more lithologically varied super crustal assemblage of intercalated Para-gneisses and calc silicate rocks all of which have been largely metamorphosed in the amphibolites facies, all of these rocks have been cut by several intrusive phases.

The present work provides a detailed account of the geology of the Qeissan area, rocks and the intrusions cutting them, their stratigraphy, structure, petrography and geochemistry are discussed.

High-grade gneisses and low grade volcano-sedimentary rocks underlain the Qeissan area. They have been folded and faulted extensively. Orogenic plutons and an orogenic ring complex have intruded these successions. A mylonitic quartz-feldthpathic zone of 3 to 6 kilometers wide is trending northeast to southwest hosting the auriferous quartz veins.

An oriented study (grid soil sampling, quartz veins and their wall rock alteration zone sampling) has been carried out to determine the anomalous area. All samples, (soil, rock & alteration zone) are prepared, analyzed and the results are interpreted using different software’s.

The soil samples shows a rather low gold grades comparing with those of quartz veins. Most of the gold is found in quartz veins and their wall-rock alteration zones. The auriferous veins are grey to milky in colour, about 1 – 3 m wide and 20 – 300 m long; often pinching and swelling up to 1 – 4 km along their strikes.

Systematic surface exploration resulted into; profile soil sampling, 0.1 – 0.92 ppm Au; rock chip sampling, 0.1 – 4.27 ppm of Au.

Keywords: Qeissan, alteration zone, anomalous, exploration, auriferous, statistical parameter.

Introduction

The study area is located in Southern part of the Blue Nile State bounded by latitude 10° 45´ to 10° 55´ N and longitude 34° 30´ to 35°00´ E (Fig.1), occupying the northwestern part of Bani-Shangul 1: 250,000 scale topographic map . The study area is covered by zone 36 Q of WGS 84 UTM, Co-ordinates system. The surface area is about 400 km². The area is accessing from Khartoum to Damazin by asphalted road (450 km) and through seasonal motorable track (170 km) to Qeissan town, takes about 10 hours driving four – wheel drive vehicles from Khartoum.

The Qeissan area lies within an undulating landscape, the base level rises to about 600 to 700 meter above sea level; Jebel Furunge is the highest pick elevation in the area.

The Qeissan area had underlain by a sequence of grey gneisses, amphibolites and volcano-sedimentary assemblages rocks forming rounded hills with low relief exposures covered with thin sandy clay and black Cotton soil. Granitoid and gabbroic rocks forming isolated bodies and plutons. Occasionally, the basement outcropped as isolated low relief hills, making the terrain undulating, with recent superficial deposits filling the dry stream valleys.

The streams are winding, narrow, shallow with gradual slope and dry to most part of the year. Khor Tumat is the dominant stream in the area, it flows northwest-north to join the Blue Nile river.

Qeissan region has a savanna to tropical climate, with a dry period from November to May and rainy season from May to October, Average rainfall is

800 mm. Temperatures are usually high through the year ranging from 18°C to 25°C in winter and average 43°C in May to July.

The vegetation is of typical Savannah grassland with scattered acacia trees and bushes .Tropical mango trees grown extensively on both eastern and western banks of Khor Tumat.

Potable water supply is rather difficult; water is obtainable from the streams only during rainy season (June-October). In the dry season, water obtainable from shallow wells dug in the stream beds.

At the Qeissan market, the government has established a water donkey, for all year round water supply. The natives of the Qeissan region obtained potable water from hand – pump wells and Khor Tumat. Recently EYAT Company has drilled water well north of the hospital for domestic uses and provides water supplies for the exploration needs.

The study area is scarcely inhabited by number of Fung tribes. They are concentrated around Qeissan and in a few scattered villages. Most of the people practice limited traditional agriculture growing sorghum in the foot of the hills and plains; some are semi-nomadic people rearing goats and sheep. Some of the people are engaged in artisan gold washing and mining especially in the rainy season or whenever, water becomes an available (photo 1), or small scale trade across the border with Ethiopia.

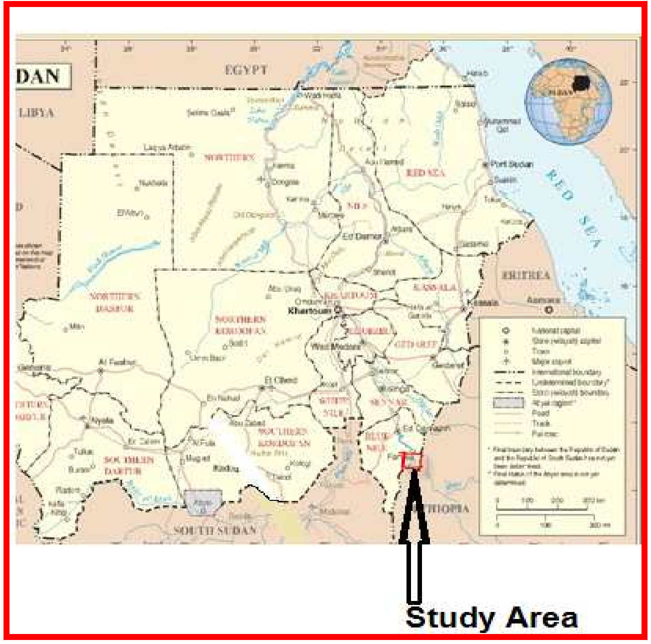

Fig.1: Location map of the study area.

Photo 1: Natives taking alluvial ore from pit of about 6m to pan for Gold (Goni area).

Geological Studies and Tectonic Setting of the Area

The Qeissan district Low grade belts belongs to the green schist facies rocks of NE Sudan which extend southwards into W- Ethiopia and Kenya to meet the N-S trending structure of the Mozambique belt, **Almond, (1980),Toum, (1985).** This belt probably represents either one of the southern extensions of the Nubian Shield as proposed by **Vail, et al., (1988)** or an allochthonous outlier of the Nubian Shield now situated in an external position, **Vail (1983).** However, it might be simply a rift /basin /arc system within the Mozambique Belt.

Vail el al., (1986) placed the Late Proterozoic low grade volcano sedimentary sequences within the lithostratigraphic sequence of the region occupying the eastern part of the South Blue Nile Province ,which probably date back to about 860 Ma. It is believed that these sequences show the effects of Pan African over printing (650-450 Ma).

The high grade quartzo-feldspathic grey gneisses occupy the northern part of the Qeissan District. These basement rocks are extending N-S direction for 30 to 50 km, separating the low- grade rocks into western and eastern belts.

The contact between the grey gneisses and the low grade green schist belts is believed to be tectonic. **Vail, et al., (1987 and 1988)** suspected the exotic inliers of the gneiss and metasedimentary terrain, particularly Qeissan block on the Blue Nile; it may be detached micro-continental block, basement floor to the younger units or locally high grade region of metamorphosed shearing and tectonism. The gneisses are metamorphosed to the amphibolite facies of regional metamorphism.

The magmatic high- grade grey gneisses are highly folded, and intruded by syn-orogenic granitoids. These continental rocks are probably unconformably overlain by supracrustal metasedimentary rocks and Para-gneisses succession.

The gneisses are grey, migmatized, medium to course grained with distinct mineral fabric. The gneisses composed of quartz feldspar, biotite, hornblende, muscovite, and sometimes almandine garnet. The age of these basements is unknown, by analogy with similar gneisses elsewhere it seems likely to be of Mid-lower Proterozoic or older.

The supracrustal metasedimentary containing Para-gneisses, pelitic and semi pelitic schist, marbles, and calc – silicates, all indicative of a shelf environment, **(Adde, A. E. and Imam, A. A., 2005; Adde, et al. 2007; Adde, A. E., Khalil, F.A. et al., 1993 and Abdel Rahaman, 1993)**. The metamorphic grade of supracrustal metasediment is high amphibolite to granulite facies and assigned to the lower Proterozoic gneiss.

Association of Pan- African volcano-sedimentary and mafic-ultramafic rocks occurred in the east and in the north around Qeissan, Kadalo and Gosu; these rocks are in direct contact with the high grade gneiss rocks characterized by zone of thrusting and mylonitization **Vail et al., (1986).** Vail called the volcano – sedimentary assemblage the Uffat Group comprising a meta-volcanic unit (Kurmuk Formation) of basic and intermediate island arc type lavas, interbeded with sedimentary sequence.

Basic meta-volcanic rocks in the area of Qeissan comprise andesitic and basaltic unit commonly intercalated with metasedimentary rocks. The basic volcanic rocks are usually fine grained, dark green in colour. Porphyritic and amygdaloidal andesites occur east of Qeissan.

In the Qeissan and Kadalo regions, numerous pre-mylonites, syn-late orogenic small plutons and masses of granites, granodiorites, diorites, hornblendites and gabbros intruded both the grey gneisses and the low-grade volcano-sedimentary rocks. The syn- late orogenic outcrop in several places e.g. J. Kadalo, J. Agaro and J. Sedo.

Gold bearing quartz veins in Qeissan region are confined to the high grade gneisses unit and low grade volcanic clastic assemblages and they are lithologically and structurally controlled **(El Rasheed et al., 2004).**

Small, relatively homogenous, minor post-orogenic dykes also occur in the area. They are mainly micro granitic, but a few acidic, basic and intermediate dyke cut across all of the above mentioned lithounits.

Post orogenic intrusions occur as non-deformed intrusions and related dykes. Oftenly, they occur as ring complexes, dykes and plugs. A representative of these intrusions is Jebel Furunge in the southeast of the area, where the ring complex is intruded syn and post tectonic granitic and the volcano sedimentary sequence. The core consists of olivine gabbros and is surrounded near vertical jointed and fractured syenite (**Fig. 2**). The latest phase at Furunge consists of felsitic dykes and less common trachytic, phonolitic and basaltic dykes. The age of an orogenic intrusive rocks facies have not been determined, however, by analogy with intrusions elsewhere in Sudan they are probably Mesozoic, **Vail, et al., (1986).**

Quaternary-recent alluvium deposit cover consists of alluvial fan deposits, gravels, sands, silts; clays, red sandy clay, and black cotton soil covered the plains, elevated areas, slope and medium relief hill and also occur as traces filling old channels or recent stream beds. Unconsolidated sand filled the downstream of Khor Tumat which drained from Ethiopia.

Materials and Methods

The field work was conducted in two seasons, February-April 2010 and January-March 2011. About 218 residual soil samples were taken from selected area at interval of 50m from sample to sample along profile and 100m from line to line using grid system by Garmin GPS map 60CS, WGS84, UTM-UPS. All samples have been collected from the upper 15 cm of the B- horizon, the samples were sieved on the site to minus 125 meshes only taken in duplicate, and the weight of each sample is about 50g. About 19 placer samples were panned in the field. 50 quarts and wall rock alteration chip samples were taken from the area representing the ore body. The samples were subjected to various preparation methods in the Geological Research Authorities of Sudan (GRAS). They were analyzed in OMAC laboratories, Ireland, with the help of X-ray Fluorescence (XRF) techniques.

The methods of investigation applied in this study include office work, geological and geochemical field works, laboratory works, and interpretation of obtained data.

Comprised and compiled the previous geological maps and related information including satellite imageries and base maps of 1:250,000 of the area.

Remote sensing digital data have been processed using soft ware's to produce image for geological mapping and geochemical sampling. The soft ware's ARC GIS 9.2, ENVI 4.2, ERDAS have been used to correct and enhance the raw digital data.

Systematic regional geological mapping was carried out through ground traverses using the Sudan survey map of scale 1: 250,000 and topographic map of scale 1: 100,000 in checking the locations and locality names. During this detailed mapping (DM), geological map of the Sudan scale 1: 250,000,000 (GRAS-2005), geological map of Qeissan area (1: 250,000, 1:100,000) by **Toum-1985**, Geological map of Qeissan (1:100,000) by **Adde, A. E., and Imam, A. A., (2007)**, Topographic map of Blue Nile Sheet at 1:250,000, (SSD-1939) and Satellite image (Land sat ETM+ scene 173/53) 2005 were used beside GPS 60Cs for locating the units

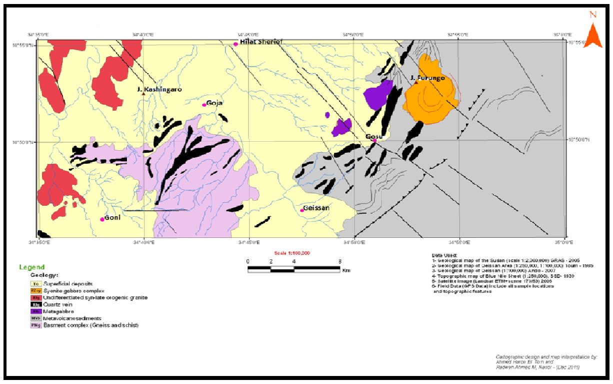

Fig. 2: Geological map of the study area.

Structure

The gneisses belt along the international border south of Kurmuk, extending into gneissic terrain north of Qeissan. These gneissic terrains can thus be regarded as ancient continental blocks, but which have been subsequently metamorphically over printed and tectonically reworked.

The supracrustal unit is appearing to have been unconformably deposited over the continental gneisses. These meta-sediments and the underlying gneisses have been subjected to high grade of regional metamorphism reaching upper amphibolite and granulite facies. The volcano-sedimentary separated from the high grade rocks by a major thrust zone along which mylonitization, crushing and tectonization have occurred.

The contact between green schist volcano-sedimentary assemblages and high grade gneisses in the vicinity of Qeissan is zone of highly mylonitized, sheared and intensely deformed rocks up to 5km wide and probably over 300 km long, **(Toum, 1985; Abdel Magid, A. E. M., 1983; Vail et al., 1986)**. Quartzo- feldspathic rock in ribbon like bands associated within thin bands of talc and graphite schist, foliated, crushed rocks predominates in the mylonite zone. These strongly developed bands of tectonics probably mark wide strike – slip shear zone, or ramped thrust, **(Vail et al., 1986; Abdel Rahaman E. M., 1983).** These assemblages are all now folded and faulted along similar structural trends up right NE trending isoclinal folds affect all of the stratigraphic units.

There are two main foliation trends in the Fazughuli - Qeissan area:

NE - SW and NNW - SSE. The former dip is 76º NW in the west, while the later dip is50 – 70º SWS in the eastern part (**Fig. 3**). In the Qeissan area faults are of three main trends: NW – SE, NE –SW and E-W and auriferous veins considerable structural control of the gold mineralization of Qeissan, **(Adde et al., 2007).**

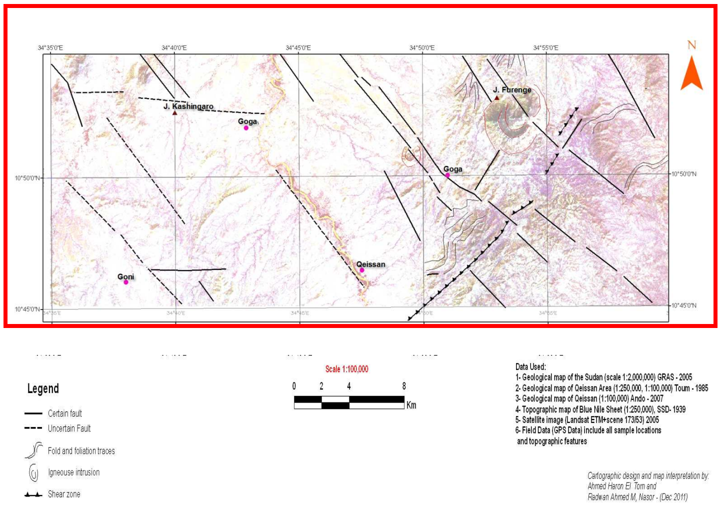

Fig. 3: Geostructural Map of the Study Area.

Mineralization

Gold mineralization occurs as white, smoky, grey quartz and pinkish white veins (Photo 2), vein-lets and stringers, ranging in thickness down depth from 0.2 meter to maximum width of 7 meter (Photo 3). They commonly pinch and swell along the strike of the quartz vein.

The quartz veins are curvenous and vugy, sometimes with inclusions and impurities from the host rocks. The intensity of quartz vein-lets varies from 2 to 15 vein-lets per 1 meter long. The vein-lets < 0.1m varies in width from 3mm to 30mm and frequently 40mm to 60mm in thickness also occur.

The main alteration mineralogy associated with quartz vein, vein lets and host rocks is pyrite, sericite, chlorite kaolinite and brown dots replaced sideritic or ankeritc.

The quartz veins and vein-lets intersections were hosted within moderately to intensively hydrothermally alter fractured and sheared quartzo-feldspathic grey gneiss. This unit is the favorable host rocks for auriferous quartz veins and vein-lets. Visible free fine gold grains observed within hydrothermal altered grey gneiss. The gold is usually free native visible, fine to very fine nature. The gold grains usually located within the fractures, caves and vugs of the white to grey white to smoky cavernous fractured quartz with iron oxide and manganese staining. The gold grains sometime associated within fine crystals of fresh pyrite aggregates or clusters and also is observed in the form of isolated grains.

Photo2: Photograph showing outcropped Smokey quartz vein.

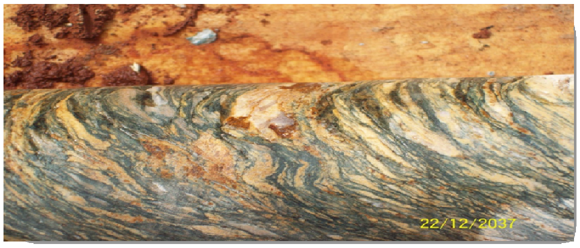

Photo 3: Photograph showing highly deformed refolded and fractured quartz chlorite schist with quartz stringers as fractures filling, core sample, Guso area.

From the chemical analysis and interpretations, it is proved that base metals are in positive correlations like Ni/Co and there is discontinuity gab in the chemical reaction probability due to various portions and due to multiple phases' enrichments of hydrothermal process.

Discussion and Statistical Evaluation of Soil and Rock Geochemical Data

Statistical Parameters

The analytical data received (**Tables 1 & 2**)from the laboratory were entered into computer on Excel sheet, and all geochemical and statistical parameters for soil samples and rock chip samples were determined using Excel, SPSS18, Surfer10, STATISTICS7 and Minpet. Different statistical analysis parameters (Univariate analysis, Bivariate analysis and Multivariate Analysis), were used in this study to identify the clusters of associated elements and the factors governing the ore.

Soil Samples Results

The correlation coefficient of soil samples data are shown in **Table 4**. For the analyzed samples (N = 218) coefficients of correlations Rs > 0.05 are significant. Weakly significant positive correlation exists between Au and Pb. Au shows significant negative correlation with other trace elements (Zn, Co, Mn, and Cu). No linear correlation between Au and Ag and this may be due to high solubility of Ag. The weak correlations between Au and these trace elements (**Table 3 & Fig. 4a, 4b, 4c, 4d and 4e**) are probably due to unrepresentative size fraction of sieving (-125 mesh).

Geochemical and statistical parameters

Summary of basic statistics for gold and trace elements with their parameters is shown in **Table 5** for all elements. Application of soil sampling is very effective in gold prospecting and exploration. However, it is difficult to calculate the anomalous values of gold. Therefore, the uses of multielements distribution pattern may helps in solving the problems and locate the mineralization zones (**Rose et al., 1983**). The pathfinder elements are searched by the aids of multivariate analysis such as correlation coefficient, Factor analysis, cluster analysis and regression analysis. To intemperate and extract maximum information from a geochemical data, a simultaneous consideration of several variables is required **(Jerome Viers, Bernard Dupre, 2002**). The most widely used multivariate analyses applied to geochemical data are **factor** and **cluster** analyses (**Davis, 1973**). A computer programs (STATISTICA, and MINPET) are used to compute factor analyses (factor loading and factor score). Two factor models have been chosen for both soil and rock data set. (**Table 5**) shows factor loading and interpretation for each factor for soil samples. **Factor 1 (**Zn, Pb, Co, Mn, Cu, Ni are positive) and (Au is negative) (**Table 3**). **Factor 2** (Zn, Cu, Ni are positive) and (Au, Pb, Co, Mn, are negative) (**Table 3**). Factor analysis technique is effective in targeting potential areas of Au mineralization (**Mohamed I. O., 2005; Mohammed A. A. 2011**). Therefore, this procedure is very helpful to be applied in reconnaissance prospecting for gold mineralization in the study area. Also factor analysis is seems to be effective in defining the geology of the study area, so it can be used in targeting lithostratigraphic units especially in areas with exposed outcrops **(Koch, G. S. and Link. R. F., 1971).**

Table 3: Results of factor analyses of trace elements for the soil samples.

	Factor 1	Factor 2
Au (ppm)	-0.264626	-0.665184
Zn (ppm)	0.270345	0.423978
Pb (ppm)	0.076884	-0.520396
Co (%)	0.866676	-0.262112
Mn (ppm)	0.866351	-0.164015
Cu (ppm	0.770427	0.034939
Ni (ppm)	0.198233	0.462622

Cluster Analysis

The multivariate anaytical method of cluster analysis has been widely applied to a variety of research problems (**Harting, 1975**) and has been especialy used in interpretation of geochemical data (**Forstner, 1983**). According to **Cooper and Thomton, (1994)**, the correlation matrics were used as the basis for clustering. The output is a special type of graphic presentation known as dendrograph (Tree Diagrame). The clustering method which produced subdivisions of the data sets into a number of clusters was applied to classify the soil samples. Four groups were identified according to the dendrograph (**Fig. 5**).

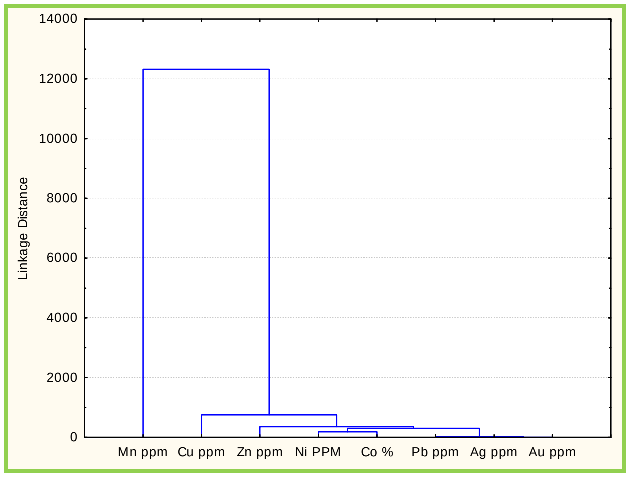

Fig. 5: Dendrograph showing the results of cluster analysis of soil samples.

Cluster 1 include (Mn, Cu, Zn), these element are related to basic to intermediate rocks.**Cluster2** include (Cu, Zn, Ni) these elements are related to basic rocks. The association of cluster one and two indicate basic to intermidiate rocks. **Cluster 3** (Zn, Ni, Co, Pb, Ag) these elements indicate basic to ultrabasic volcanic rocks. **Cluster 4** (Ni, Co) these element indicate ultrabasic volcanic rocks.

From the above mentioned information it is evident that the use of the technique of cluster analysis in evaluating the soil data is effective in geological mapping.

Threshold and anomalous values

The threshold is the upper limit of the normal background value. All values above the thresholds are considered as anomalous value, therefore; it may indicate the presence of a mineral deposit or occurrence in near vicinity. According to **Levinson (1980)** anomaly is defined as a deviation or departure from the norm. Standard deviation has been used to calculate the threshold and anomalous values and the threshold values of all elements summarized in the **Table 5.**

Background Values (Be)

The background value is the natural base load. From geochemical point of view, the term background is equivalent with the absence of an anomaly. The term was coined by exploration geochemistry in order to differentiate between the element concentration within a rock matrix devoid of enrichments and those rock parts that show positive anomalies, **W. M. White, (2005).** In this study it is equal to the Mean (M).

Table.4: Correlation values between elements in soil sample results.

	Au	Ag	Zn	Pb	Co	Mn	Cu
Ni	-0.14	0	0.03	0.02	0.08	0.07	0.1
Cu	-0.22	0	0.14	0.08	0.54	0.46	
Mn	-0.12	0	0.17	0.11	0.76		
Co	-0.01	0	0.07	0.08			
Pb	0.04	0	-0.06				
Zn	-0.12	0					
Ag	0						

Table 5: Descriptive statistics and statistical parameters of trace elements data.

	Valid N	**Mean**	**Median**	**Minimum**	**Maximum**	**Variance**	**Std.Dev.**	**Backg. value (b)**	**threshold**	**C.v**
Au ppm	218	0.15	0	0	0.92	0.05	0.2299	0.15	0.6098	0.652458
Zn ppm	218	38.2385	35.5	13	111	258.32	16.0724	38.2385	70.3833	2.379141
Pb ppm	218	1.211	0	0	6	2.93	1.7124	1.211	4.6358	0.707195
Co %	218	20.7156	20	7	44	47.28	6.8762	20.7156	34.468	3.012652
Mn ppm	218	853.3486	796	268	2155	93736.94	306.1649	853.3486	1465.678	2.787219

Cu ppm	218	71.0046	63.5	6	222	1419	37.6696	71.0046	146.3438	1.884931
Ni ppm	218	22.3578	21	7	84	117.59	10.8441	22.3578	44.046	2.061748

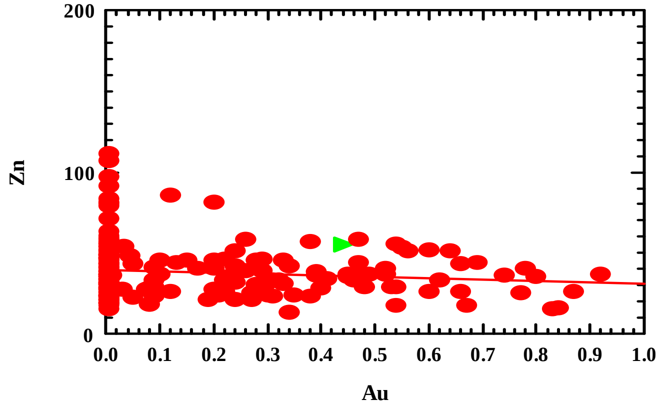

Fig.4a: Au vs Zn in soil samples.

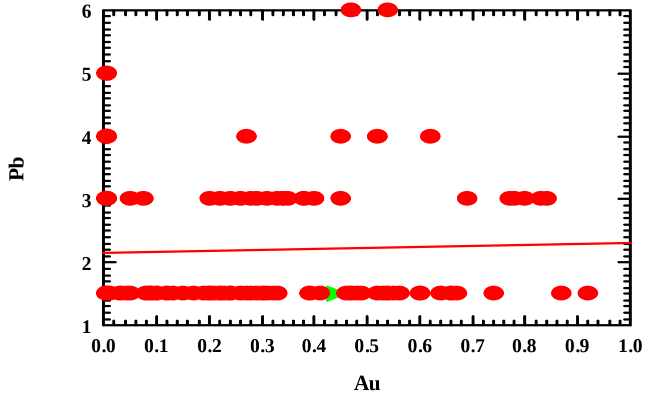

Fig. 4b: Au vs Pb in soil samples.

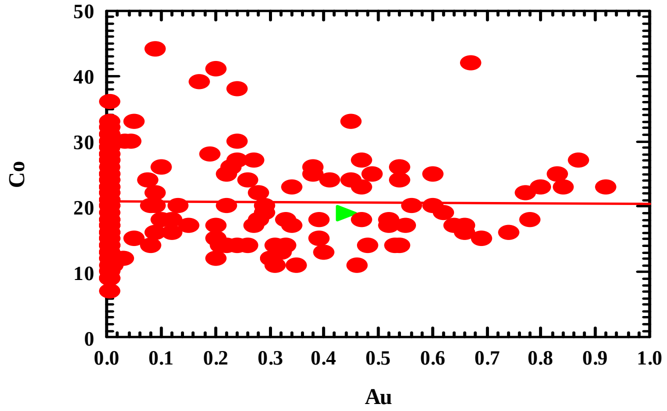

Fig. 4c: Au vs Co in soil samples.

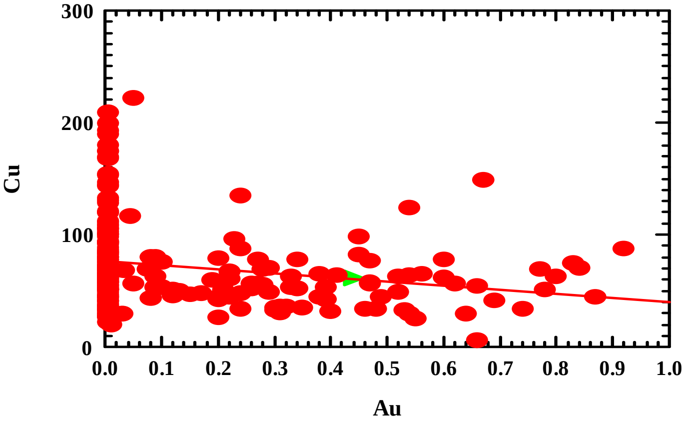

Fig. 4d: Au vs Cu in soil samples.

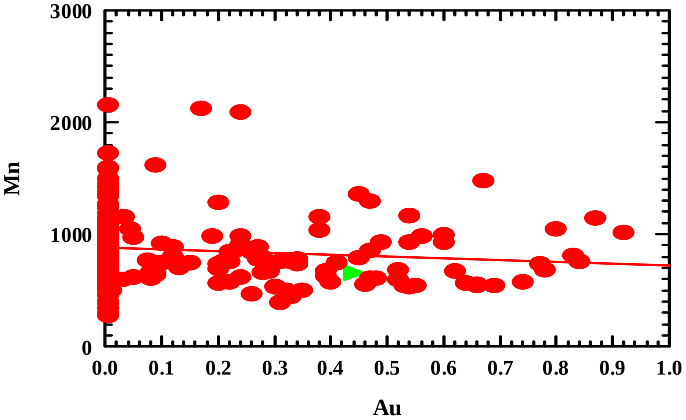

Fig. 4e: Au vs Mn in soil samples.

The Au, Zn, Pb, Co, Mn, Cu and Ni concentrations in soil samples varies between, 0-0.92ppm; 13-1111ppm;0-4ppm; 7ppm-44%;268-2155ppm; 6- 222ppm and 7- 84ppm respectively. Arithmetic means are 0.15ppm; 38.2385ppm; 1.211ppm; 20.7156%; 853.3486ppm; 71.0046ppm and 22.357ppm, respectively. Variance 0.015ppm; 258.32ppm; 2.93ppm; 47.28%; 93736.93ppm; 1419ppm; and 117.59ppm.Standard deviations are 0.2299ppm; 16.0724ppm; 1.7124ppm; 6.8762%; 306.1649ppm; 1.88493ppm and10.8441ppm. The background values and thresholds are 0.151ppm and 0.6098ppm; 38.2385 and 703833ppm; 1.211 and 4.6358ppm; 20.7156 and 34.4668ppm; 853.3486 and 1465.678ppm; and 71.0046 and 146.3438ppm; 22.3578 and 44.046ppm respectively. The coefficient of variations (C.v.) are 0.65245%; 2.37914%; 0.70710%; 3.01265%; 2.7872%; 1.8894% and 2.0617% respectively.

Au is low; therefore, it is possible to say the distribution of gold in soil is homogenous and normal. It is evident that the area of high concentration of Ni is also with considerable values of gold.

Rock Sample Results

The results of chemical analysis of rock samples for gold and trace elements are shown in **Table 6**.

Table 6: Descriptive statistics and statistical parameters of trace elements data for rock samples.

	Valid N	Mean	Median	Minimum	Maximum	Variance	Std. Dev.	Back g. v.	Threshold	C.v.
Au ppm	19	0.035789	0.005	0.005	0.17	0.00268	0.051727	0.035789	0.139243	0.691882
Ag ppm	19	0.023105	0.019	0.001	0.058	0.00046	0.021385	0.023105	0.065875	1.08043
Zn ppm	19	0.449053	0.209	0.005	1.056	0.17405	0.417192	0.449053	1.283437	1.07637
Pb ppm	19	0.000768	0.0001	0.0001	0.008	0	0.001971	0.000768	0.00471	0.38965
Co %	19	0.020105	0.013	0.004	0.08	0.00035	0.018687	0.020105	0.057479	1.075882
Mn ppm	19	7.648947	6.16	0.317	15.6	32.57385	5.70735	7.648947	19.06365	1.340192
Cu ppm	19	0.042053	0.022	0.006	0.33	0.00525	0.072479	0.042053	0.187011	0.580209
Ni PPM	19	0.029211	0.014	0.001	0.104	0.00112	0.033393	0.029211	0.095997	0.874764

The Au, Ag, Zn, Pb, Co, Mn, Cu and Ni concentrations in rock samples ranges between 0.005 to 0.17ppm; 0.001 and 0.058ppm; 0.005 and 1.056ppm; 0.0001 to 0.008ppm; 7 and 44%; 0.317 to 15.6ppm; 0.006 to 0.33ppm; and 0.001 to 0.104ppm. The arithmetic means are 0.035789ppm; 0.023105ppm; 0.449053ppm; 0.000768ppm; 20.7156%; 7.648947ppm; 0.042.53ppm; 0.029211ppm. Variances are 0.00268ppm; 0.691882%; 0.17405ppm; 0.0ppm; 47.28ppm; 32.57385ppm; 0.00525ppm and 0.00112ppm respectively. The Standard Deviations are 0.051727ppm; 0.021385ppm; 0.417192ppm; 0.001971ppm; 6.8762ppm; 5.70735ppm; 0.072479 ppm; and 0.033393ppm respectively. The background value and threshold are 0.035789ppm and 0.139243ppm; 0.023105ppm and 0.065875ppm; 0.449053ppm and 1.283437ppm; 0.000768ppm and 0.00471ppm; 20.7156% and 34.468%; 7.648947ppm and 19.06365ppm; 0.04205 3and 0.187011ppm and 0.00113 and 0.095997ppm respectively. The coefficient variations (C.v.) are 0.691882%; 0.691882%; 1.07637%; 0.38965 %; 3.01265%; 1.340192%; 0.580209ppm and 0.874764%. The coefficient of variation (C.v.) of Au and other pathfinders are low, and therefore, it is possible to say the distribution of gold in rock is homogenous and normally distributed.

Table 7: Correlation values between elements in rock sample results.

	Au ppm	Ag ppm	Zn ppm	Pb ppm	Co %	Mn ppm	Cu ppm	Ni PPM
Au ppm	1							
Ag ppm	-0.39	1						
Zn ppm	0.39	0.33	1					
Pb ppm	0.18	-0.33	-0.22	1				
Co %	0.59	-0.17	0.14	0.21	1			
Mn ppm	0.51	0.27	0.96	-0.19	0.3	1		
Cu ppm	-0.02	0.32	-0.1	0	-0.16	-0.11	1	
Ni PPM	0.73	-0.07	0.73	-0.17	0.48	0.76	-0.07	1

Multivariate Analyses

To intemperate and extract maximum information from a geochemical data, a simultaneous consideration of several variables is required. The most widely used multivariate analyses applied to geochemical data are **factor** and **cluster** analyses.

Factor Analysis

Factor analysis was used to evaluate the geochemical data. A computer programs (STATISTICA, and MINPET) are used to compute factor analyses (factor loading and factor score) for both rock and soil sample chemical results. Two factor models have been chosen for rock data set. (**Table 7**) shows factor loading and interpretation for each factor for soil samples.

Factor 1 (Au, Ag, Zn, Co, Mn, Ni are positive) and (Pb, Cu are negative). **Factor 2** (Ag, Zn, Mn, Ni are positive) and (Au, Pb, Co, Ni, are negative) (**Table 8**).

Table 8: Results of factor analyses of trace elements for the rock samples.

	Factor1	**Factor2**
Au ppm	0.758684	-0.47989
Ag ppm	0.029476	0.838565
Zn ppm	0.850479	0.409068
Pb ppm	-0.11489	-0.64397
Co%	0.548724	-0.50222
Mn ppm	0.911362	0.3003
Cu%	-0.14688	0.305007
Ni ppm	0.92786	-0.03861
Expl.Var	3.327161	1.952447
Prp.Totl	0.415895	0.244056

Cluster Analysis

The clustering method which produced subdivisions of the rock data sets (**Table 8**) into a number of clusters was applied to classify the rock samples. Four groups were identified according to the dendrograph (**Fig. 6**).

Cluster 1 (Mn, Zn, and Cu) this group of elements related to basic to intermediate rocks. **Cluster 2** (Zn, Cu, and Ni) this group of elements also related to basic rocks. **Cluster 3** (Cu, Ni, Co, Pb) this group of elements related to basic volcanic rocks. **Cluster 4** (Ni, Co, Pb, Ag, and Au) this group of elements related to basic volcanic rock.

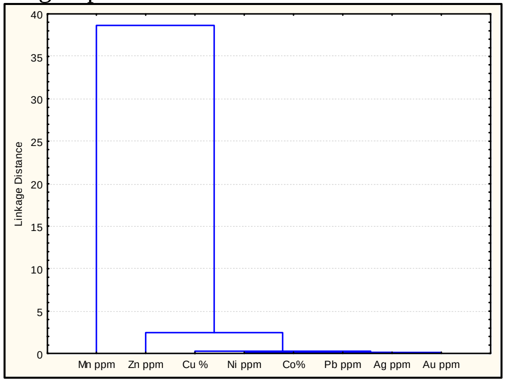

Fig. 6: Dendrograph showin the results of cluster analysis of rock samples.

Table 9: Geochemical Analyses of Rock Chip Samples.

Sr. No.	Sam. No.	Au (ppm)	Ag (ppm)	Zn (ppm)	Pb (ppm)	Co (%)	Mn (ppm)	Cu (%)	Ni (ppm)	Rock type
1	GTH01	0.06	ND	0.095	0.008	0.04	2.693	0.03	0.009	Quartz feld. Gneisses
2	GTH10	0.04	0.006	0.209	0.004	0.013	6.16	0.055	0.01	Quartz feld. Gneiss
3	GTH02	0.17	0.01	0.981	0.001	0.033	15.6	0.08	0.072	metabasite
4	GTH11	ND	0.052	0.107	ND	0.006	2.383	0.33	0.014	metabasite
5	GTH09	ND	0.002	0.091	ND	0.007	3.611	0.027	0.002	Metabasite
6	STH05	ND	0.055	1.056	ND	0.005	15.15	0.02	0.016	metabasite
7	GTH03	0.14	0.008	0.73	ND	0.080	15.2	0.017	0.104	Granodiorite
8	STH06	ND	0.049	0.632	ND	0.004	9.78	0.007	0.05	amphibplite
9	STH08	0.05	0.058	0.881	ND	0.041	14.62	0.027	0.053	amphibolite

10	GTH05	0.12	0.001	0.868	ND	0.008	12.14	0.022	0.092	Gabro
11	GTH06	0.05	0.002	0.828	ND	0.012	10.01	0.007	0.061	Gabro
12	STH01	ND	0.045	0.892	ND	0.025	12.46	0.04	0.042	Gabro
13	STH04	ND	0.019	ND	ND	0.007	0.317	0.032	ND	White quartz vein
14	STH02	ND	0.025	ND	ND	0.017	0.338	0.006	0.004	White Quartz vein
15	STH07	ND	0.045	0.924	ND	0.006	13.23	0.055	0.019	Sericite schist
16	STH09	0.04	0.028	ND	ND	0.027	0.363	0.012	ND	Quartz. muscovite schist
17	STH03	ND	0.029	0.069	ND	0.02	4.043	0.013	0.002	Chl. schist
18	GTH07	ND	0.001	0.095	ND	0.022	3.538	0.013	ND	Chl. mica schist
19	GTH08	0.04	0.003	0.059	ND	0.009	3.694	0.006	ND	Quartz. chl. schist
20	GTH04	0.15	0.004	0.952	ND	0.005	12.86	0.012	0.011	Biotite, chl. schist

The Gold concentration in soil ranges between 0.00 and 0.92ppm with arithmetic mean of 0.15, Variance 0.05 standard deviation of 0.2299. It is evident from Fig.4a, 4b, 4c, 4d, 4e and Skewness, the gold is normally distributed in soil. The background and threshold of Au are 0.151ppm and 0.6098 respectively, and coefficient variation (C.v.) of 0.65245%.

The coefficient of variation (C.v.) of Au is low; therefore, it is possible to say the distribution of gold in soil is homogenous and normal. It is evident that the area of high concentration of Zn (Fig. 4a, 4b, 4c, 4d, and 4e) is also with considerable values of gold.

Conclusion and Recommendation

►The detailed geological mapping carried out in the present work has revealed the presence of high-grade gneisses and high grade supracrustal metasediments including gneiss, metabasite and amphibolites and low-grade metavolcanics, they have been folded and faulted extensively. Orogenic plutons and anorogenic ring complexes have intruded these successions.

►The presence of green schist assemblage within the high-grade rocks suggests that the area has suffered from retrogressive metamorphism.

►Field observations have revealed that most of the Au-mineralization is hosted by pelitic gneisses and metavolcano-sediments, occurring mainly in fissure filling quartz veins, vein lets, and stringers that occupy faults planes structurally control the Au-mineralization in the study area.

►Gold concentration in soil is rather low grade ranging from .001 to 0.92 ppm comparing with those of quartz vein ranging from 0.01 to 4.27 ppm (Table 2 &3).The mean calculated for Au in soil was 0.15ppm, while for rock was 0.0357ppm

►A structural control of the mineralization has been noticed in the area, it is important to carry out more detailed structural study.

►The soil sample geochemical methods are most easy and quick to trace the geochemical hallows, therefore, it is recommended to be done in the whole area of the same trend and lithology with the study area.

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Table1 : Geochemical analyses of soil samples

Sr. N	Sample No.	Au (ppm)	Ag (ppm)	Zn (ppm)	Pb (ppm)	Co (%)	Mn (ppm)	Cu (ppm	Ni (ppm)
1	Gos 1	0.44	< 0.5	55	0	19	653	61	32
2	Gos 2	0.54	< 0.5	55	6	24	1162	64	54
3	Gos 3	0.47	< 0.5	44	6	27	1292	76	29
4	Gos 4	0.45	< 0.5	37	4	33	1355	98	25
5	Gos 5	0.41	< 0.5	34	0	24	741	64	24
6	Gos 6	0.62	< 0.5	33	4	19	665	56	25
7	Gos 7	0.47	< 0.5	36	0	18	599	57	31
8	Gos 8	0.29	< 0.5	39	3	20	706	70	30
9	Gos 9	0.38	< 0.5	57	3	26	1037	65	23
10	GoS10	0.29	< 0.5	46	0	19	671	49	31
11	Gos 11	0.13	< 0.5	44	0	20	700	50	32
12	Gos 12	0.10	< 0.5	45	0	18	746	53	28
13	Gos 13	0.26	< 0.5	39	0	14	468	52	39

14	Gos 14	0.09	< 0.5	41	0	16	658	53	42
15	Gos 15	0.00	< 0.5	31	0	17	675	57	45
16	Gos 16	0.00	< 0.5	30	0	16	691	40	29
17	Gos 17	0.00	< 0.5	29	4	15	518	33	37
18	Gos 18	0.00	< 0.5	45	0	18	2155	32	26
19	Gos 19	0.00	< 0.5	37	0	15	709	34	28
20	Gos 20	0.00	< 0.5	35	0	16	836	26	29
21	Gos 21	0.00	< 0.5	24	3	17	787	44	25
22	Gos 22	0.12	< 0.5	26	0	18	801	45	27
23	Gos 23	0.31	< 0.5	23	0	11	391	36	25
24	Gos 24	0.20	< 0.5	45	0	12	557	26	15
25	Gos 25	0.74	< 0.5	36	0	16	573	33	14
26	Gos 26	0.52	< 0.5	40	0	17	590	49	23
27	Gos 27	0.39	< 0.5	38	3	15	622	42	20
28	Gos 28	0.33	< 0.5	31	0	14	445	53	22
29	Gos 29	0.34	< 0.5	42	3	17	772	52	13
30	Gos 30	0.20	< 0.5	40	3	15	688	42	13
31	Gos 31	0.00	< 0.5	41	0	21	1020	57	11
32	Gos 32	0.24	< 0.5	51	3	38	2084	47	9
33	Gos 33	0.17	< 0.5	40	0	39	2120	48	9
34	Gos 34	0.28	< 0.5	30	0	22	789	69	13
35	Gos 35	0.22	< 0.5	33	3	14	571	44	8
36	Gos 36	0.30	< 0.5	32	0	12	527	35	7
37	Gos 37	0.48	< 0.5	29	0	14	602	34	10
38	Gos 38	0.32	< 0.5	33	0	13	499	36	13
39	Gos 39	0.31	< 0.5	33	3	14	758	30	7
40	Gos 40	0.46	< 0.5	33	0	11	554	33	8
41	Gos 41	0.03	< 0.5	27	0	12	588	29	11
42	Gos 42	0.00	< 0.5	29	0	14	592	36	21
43	Gos 43	0.00	< 0.5	38	0	13	594	27	18
44	Gos 44	0.00	< 0.5	47	0	13	590	27	16
45	Gos 45	0.00	< 0.5	34	0	17	538	43	43
46	Gos 46	0.00	< 0.5	43	0	25	988	51	43
47	Gos 47	0.15	< 0.5	45	0	17	743	46	84
48	Gos 48	0.00	< 0.5	42	0	25	1076	37	17
49	Gos 49	0.00	< 0.5	46	0	20	531	55	14
50	Gos 50	0.00	< 0.5	34	0	16	582	44	18
51	Gos 51	0.20	< 0.5	27	0	17	729	44	14
52	Gos 52	0.35	< 0.5	24	3	11	500	35	15
53	Gos 53	0.30	< 0.5	24	0	12	527	32	11
54	Gos 54	0.40	< 0.5	28	3	13	572	31	12
55	Gos 55	0.00	< 0.5	41	0	13	569	31	12
56	Gos 56	0.24	< 0.5	21	0	14	612	34	13
57	Gos 57	0.38	< 0.5	23	3	25	1147	44	12
58	Gos 58	0.53	< 0.5	29	0	14	538	32	10
59	Gos 59	0.39	< 0.5	36	0	18	672	53	12
60	Gos 60	0.64	< 0.5	51	0	17	558	29	18
61	Gos 61	0.55	< 0.5	53	0	17	543	25	18
62	Gos 62	0.28	< 0.5	45	3	18	655	55	17
63	Gos 63	0.33	< 0.5	45	3	18	755	63	12
64	Gos 64	0.66	< 0.5	43	0	17	540	6	17
65	Gos 65	0.26	< 0.5	58	3	24	840	56	18
66	Gos 66	0.47	< 0.5	58	0	23	851	56	18
67	Gos 67	0.56	< 0.5	51	0	20	983	65	32
68	Gos 68	0.60	< 0.5	52	0	20	930	78	23
69	Gos 69	0.52	< 0.5	37	4	18	679	63	23
70	Gos 70	0.8	< 0.5	35	3	23	1041	63	30

71	Gos 71	0.87	< 0.5	26	0	27	1143	44	27
72	Gos 72	0.49	< 0.5	37	0	25	930	44	41
73	Gos 73	0.54	< 0.5	29	3	14	533	29	24
74	Gos 74	0.6	< 0.5	26	0	25	987	61	18
75	Gos 75	0.074	< 0.5	27	3	24	762	69	10
76	Gos 76	0.77	< 0.5	25	3	22	733	69	12
78	Gos 77	0.84	< 0.5	16	3	23	749	70	12
79	Gos 78	0.83	< 0.5	15	3	25	812	74	7
80	Gos 79	0.66	< 0.5	26	0	16	547	54	19
81	Gos 80	0.69	< 0.5	44	3	15	538	41	8
82	Gos 81	0.78	< 0.5	40	3	18	675	51	12
83	Gos 82	0.92	< 0.5	37	0	23	1012	87	18

Table 2: Geochemical analyses of quartz vein chip samples.

Sr. No.	Sam. No.	Au (ppm)
1	G0c1	0.04
2	Goc2	0.03
3	Goc3	1.04
4	Goc4	0.03
5	Goc5	0.04
6	Goc6	0.05
7	Goc7	0.05
8	Goc8	0.077
9	Goc9	0.55
10	Goc10	0.27
11	Goc11	0.50
12	Goc12	0.05
13	Goc13	0.02
14	Goc14	0.03
15	Goc15	0.02
16	Goc16	0.03
17	Goc17	0.06
18	Goc18	4.27
19	Goc19	0.65
20	Goc20	6.25
21	Goc21	0.03
22	Goc22	0.02
23	Goc23	0.05
24	Goc24	0.45
25	Goc25	0.06
26	Goc26	0.05
27	Goc27	2.17
28	Goc28	0.02
29	Goc29	0.04
30	Goc30	0.04
31	Suc31	0.33
32	Suc32	0.05
33	Suc33	0.15
34	Suc34	0.1
35	Suc35	0.2