Palynology and source rock potential studies of the Tura Formation in the Garo Hills, Meghalaya (India)

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Abstract

Here, a rich palynological assemblage from the Tura Formation consisting of dinoflagellate cysts, fungal remains; spores and pollen grains, along with a numerous marine microforaminiferal linings. The composition of palynotaxa indicates a warm, humid climate with tropical-subtropical climate conditions during sediment deposition. Based on similar palynofloral assemblages, we conclude that the Tura Formation was deposited during late Paleocene to early Eocene. The presence of terrestrial, coastal and marine elements in the assemblages is indicative of a shallow marine environment in proximity to the shore line. The rock eval pyrolysis results suggest that the organic matter composition has a mixed type kerogens II, III & IV which are immature to marginal mature with oil and gas prones.

Introduction

The Paleogene period succeeds the Cretaceous and subdivides into the Paleocene, Eocene and Oligocene epochs. The stratigraphic records of Paleogene successions are mainly exposed at a number of places of Tethys and Lesser Himalayas, Hills of Meghalaya, Andaman, Rajasthan, Gujarat and Puducherry in India. In Meghalaya, the Paleogene successions are represented by the Tura, Siju, Rewak and Kopili formations in the Garo Hills. The late Paleocene -early Eocene of the Tura Formation of Garo Hills has a rich of palynological assemblages of spores and pollen grains and dinoflagellate cysts. Here we provide detailed depositional environment and source rock potential of the Tura Formation in Garo Hills based on palynology, Rock Eval evaluation and degree of organic maturation.

Geological setting

The Shillong Plateau is a remnant of the north-easterly extension of the Indian Peninsula which underwent multiple phases of deformation. The Garo Hills is a part of the Shillong Plateau on the westernmost part of Meghalaya and located in the south of the Tura Ranges which is bounded to the south by the Dapsi fault (Fox, 1937) in Bangladesh, in the north and the west by Assam, and in the east by the West Khasi Hills district of Meghalaya (Figure 1). The oldest stratigraphic unit of granite and granite gneisses of Precambrian basement in the Garo Hills is unconformably overlain by the Lower Gondwana sediments and Tertiary sediments. The rocks of the Tura Formation expose in the north and south of Tura Range and their exposure increases towards east where they form outliers over the Precambrian basement. The basal sedimentary succession in the Garo Hills is represented by the Tura Formation (Biswas, 1962), consists of clastic sediments, dominantly sandstones and shales with coal-bearing units. The Tura Formation is overlain conformably by the fossiliferous Siju Formation. This formation consists of hard, yellow, arenaceous and fossiliferous limestone with shale and marl. This succession is followed by the predominantly argillaceous Rewak and younger successions.

Material and Methods

Shale samples were collected from different sections (Figure 2) of the Tura Formation in the Garo Hills, Meghalaya (Tura sections-TD, TG, DP, DS, HG, SW4, TB1, SW2, AS1, BS1, BS2). About 500mg of each unweathered shales were chemically processed by using hydrofluoric (40% for two days), hydrochloric (35% for one day), nitric acids (69-72% for few minutes) and heavy liquid ($ZnCl_2$+HCl; density 2.0 gcm^{-3}) in the different duration. After extensive mixing to obtain homogeneity, four to eleven slides were prepared using a mountant Canada balsam. The quantitative and qualitative palynological analyses were done based on the presence of palynomorphs in the slides. Photomicrography has been done by microscopes with digital camera attachment (Nikon Eclipse LV

100 NPOL; Nikon Eclipse E200) for further study. The selected samples of the Tura Formation have been powdered for determination of source rock evaluation. TOC analysis and other rock eval parameters have been performed by Rock Eval – VI at KDMIPE, ONGC Dehradun. The slides after treatment with HC and HF acids were observed visually for Thermal Alteration Index (TAI) and organic content under a transmitted light microscope of Nikon Eclipse LV 100N POL and E-200 (Staplin, 1969). The source rock potential of the Tura Formation has been evaluated based on the quantity and quality of organic matter, and maturity.

Figure 1

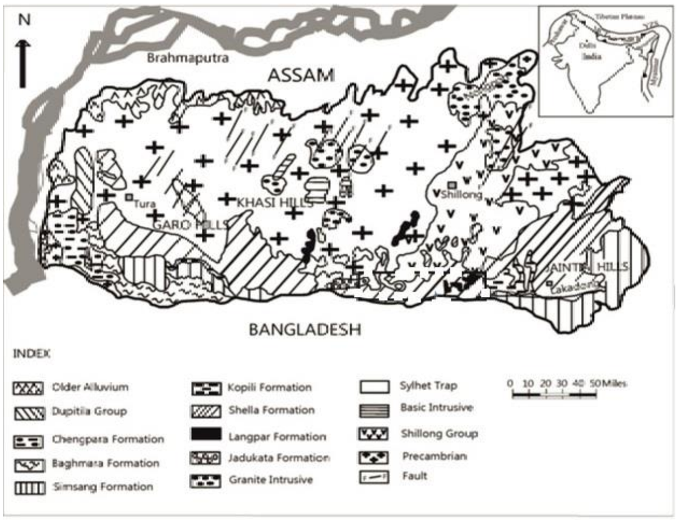

Figure 2

Figure 1: Geological map of Meghalaya.
Figure 2: Tura succession along (a,b). Tura-Damalgre Road; Tura succesion at (c). Garobada Bazar (d). Siju village, (e-f). Nongalbibra (e, lower part; f, upper part), (g). Tura Bus stand (h). Tura succession along Dalmagre-Milemgree Road.

Depositional Environment and Palaeoclimate

The overall palynological assemblage points towards a tropical-subtropical, humid climate during the deposition of these sections. The higher percentage of coastal element such as *Proxaperties, Neocouperipollis* and *Palmidites* with freshwater element indicates that the deposition of these sediments took place under coastal environment. Absences of dinoflagellate cyst in the upper and middle part of these sections are suggestive of decreasing marine influence during this phase of deposition. In section SW4, the overall assemblage indicates a warm and humid climate with tropical-subtropical climate and coast area with influx of freshwater during deposition of this section. In TG and DS1 Sections, dominance of freshwater element of pteridophytes over the marine is indicative of terrestrial environment during deposition of this section under tropical-subtropcial with humid and warm and heavy rainfall climate in condition. In the section TD, fungal remains are well distributed in all the horizons which indicate warm and humid conditions with heavy rainfall. The dominance of dinoflagellate cysts and microforaminiferal linings in the lower and upper part of this section is indicative of shallow marine conditions during the sedimentation of Tura sediments. In HG section, fungal and *Lanagiopollis* spp. are well distributed throughout the section. The marine elements of dinoflagellate cysts and foraminiferal linings are recorded at lower and middle parts of section. The prevalence of tropical-subtropical conditions is evident from the composition of the palynofloral assemblages. On the basis of the occurrence of dinoflagellate cysts and foram in the lower and middle parts, it is reasonable to infer a shallow marine environment of deposition and the upper part of section was deposited in close proximity to the shore line based on *Proxapertites*, *Longiopollis,* and *Nymphacidites*. In TB1 section, the assemblage contains a mixture of land, coastal, mangrove and marine elements. The fungal remains, dinoflagellate cysts and foraminiferal linings are distributed all horizons of section. Based on marine elements, this section was deposited under warm, humid, shallow marine environment with tropical-subtropcal conditions. In SW2 section, a rich composition of palynoflora indicates shallow marine environments due to the dominance of dinoflagellate cysts over mangrove palynofossils. Marine elements are dominating in the upper part of section but no marine element at lower part and it is dominating by coastal element. Most of the families represented in the assemblage recovered from this section are presently distributed in tropical to subtropical regions. In BS1 section, the assemblage from the lower and middle parts of the studied section is rich in in pollen having affinity with the families Arecaceae and Gunneraceae which are plants of coastal forest. These parts of section were deposited under coastal environment. The assemblage from the upper part shows the presence of palynofossils having affinity of with family Arecaceae and dinoflagellate cysts indicating that the deposition of these sediments took place under shallow marine conditions. The palynofloral spectrum recovered from this section indicates that these sediments were deposited in the shallow marine under warm, humid with tropical to subtropical condition. The occurrence of palynological assemblage from the BS2 section indicates a coastal environmental condition. In Rongmeram River section DP, the higher percentage of marine elements represented by dinoflagellate cysts and foraminiferal linings alongwith fungal remains with a minor coastal elements viz. *Palmidites* and *Matanomadhiasulcites* and lowland element of *Tricolpillites*. The overall vegetation patterns suggests a tropical-subtropical (represented by families Alangiaceae, Bombacaceae and Arecaceae), warm, humid and shallow marine environment during deposition of this section.

Age of Tura Formation

The detailed dinoflagellate cyst has not been carried out by the earlier workers. In the present study, the preservation of the dinoflagellate cysts is fairly good and allows identification of age diagnostic speices. Besides speices of *Homotryblium*, the assemblage is dominated by *Operculodinium centrocarpum*, *Cordosphaeridium* spp., and *Polysphaeridium* spp. in almost all sections (Figure 3). Characteristic speices having known stratigraphic first occurrence (FOD) in the late Paleocene include *Homtryblium tenuispinosum, Apectodinium homomorphum, Lingulodium machaeophorum, Thalassiphora delicate, Achomosphaera alcicornu,* and *Araneosphaera araneosa*. Dinotaxa with FO in the early Ypresian include *Glaphyrocysta exuberans, Clesitosphaeridium diverspinosum* and the dinoflagellate cysts have been reocevered from the different traverse of Garo Hills. The FAD and LAD of common dinocysts from Tura Formation are: The FO of *Apectondium homomorphium* in the TB1 section recovered from the Tura Formation indicates a Late Thanetian age, close to the Paleocene-Eocene boundary (Powell, 1992; Brinkhuis et al., 1994); FO of *Glaphyrocysta exuberans, Operculodinium severinii* and *Adnatosphaeridium multispinosum* in the assemblage of the Tura Formation is also significant in the present context as this species has its FAD at the base of Ypresian. The FAD of *Adnatosphaeridium multispinosum, Areosphaeridium diktyoploka* in the assemblage indicates an earliest Ypresian age. Further, the stratigraphically most significant dinocysts are *Achomosphaera alcicornu, Cleistosphaeridium diversispinosum* which support the above Ypresian age. The above account of suggests that the Tura Formation ranges in age from late Paleocene to early Ypresian (early Eocene).

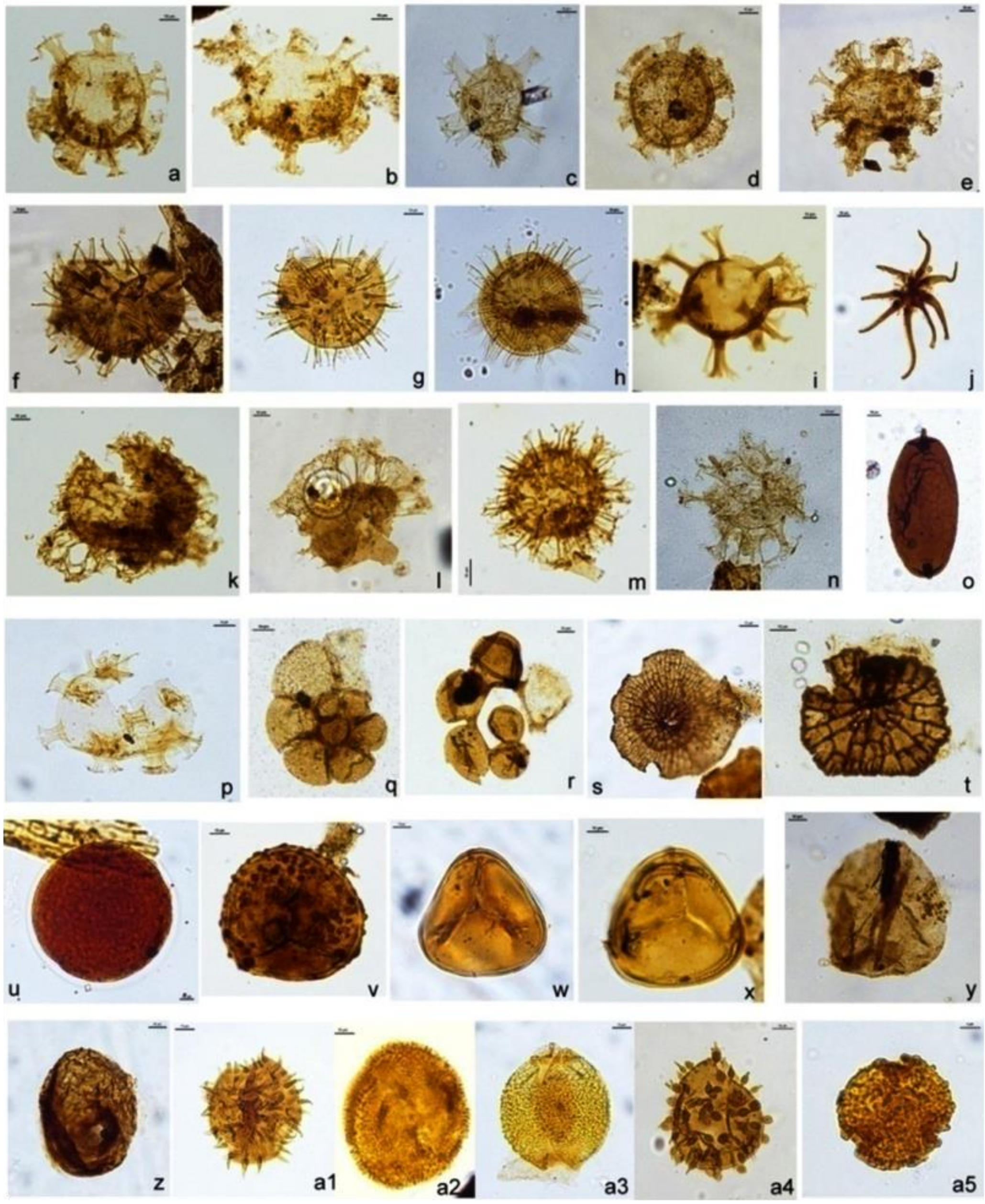

Figure 3: a). *Cordosphaeridium inodes*, TB1-3,4,3b; a1). *Neocouperipollis brevispinosus*, TB1-1,6,2; a2). *Tricolporopollis robustus*, TB1-2,6,3; a3). *Longapertites hammenii*, TB1-1,9,44; a4). *Neocouperipollis kutchensis*, TB1-4,6,12; a5). *Tricolporopillites uniformis*, TB1-1,9,21; b). *Homotryblium tenusinosum*, TB1-3,4,3a; c). *Cordosphaeridium inodes*, TB1-1,6,9; d). *Cordosphaeridium gracile*, TB1-5,4,4; e). *Cordosphaeridium cantharellium*, TB1-3,5,8; f). *Operculodinium major*, TB1-4,6,8; g). *Operculodinium centrocarpum*, TB1-1,7,3a; h). *Operculodinium centrocarpum*, TB1-1,8,3; i). *Homotryblium tenuispinosum,* TB1-5,3,9; j). *Parmathyrites robustus*, TB1-1,7,15b; k). *Adnatosphaeridum multispinosum*, TB1-3,4,2; l). *Glaphyrocysta exuberans*, TB1-5,4,2b; m). *Apectodinium homomorphum*, TB1-5,3,5; n). *Achomosphaera alcicormu*, TB1-1,3,8a; o). *Didymoporisporonites gigas fungal*, TB1-1,2,15; p). *Homotryblium vallum*, TB1-1,9,12; q). *Trochospiral* type I, TB1-1,2,19; r). *Planispiral* type II, TB1-3,1,1; s). *Phragmothyrites eocaenicus*, TB1-1,7,21; t). *Phygmothyrites eocaenica*, TB1-1,3,4c; u). *Proxapertites cressimurus*, TB1-1,8,14; v). *Lycopodiumsporites palaeocenicus*, TB1-1,2,5; w). *Lygodiumsporites eocenicus*, TB1-1,8,18; x). *Intrapunctisporis gigantic*, TB1-1,3,31; y). *bInapertisporites kedvesii*, TB1-5,6,16; z). *Polypodiisporites repandus*, TB1-1,7,34a.

Source rock potential

TOC of the Tura Formation ranges between 0.33 and 64.98% (Table 1). The genetic potential (S1+S2; mg HC/g rock) of these samples varies from 0.17 to 330 mgHC/g rock. Richness of the samples ranges from poor to rich. Most of samples are in mixed type of kerogens II, III & IV (Figures 4, 5) under immature to marginal mature Samples (SW4-4,5,7 and BS2-3) fall in type II and oil prone area (Figure 4). However, source rock potential of Tura Formation shows a mixed oil and gas prone organic matter/kerogen facies.

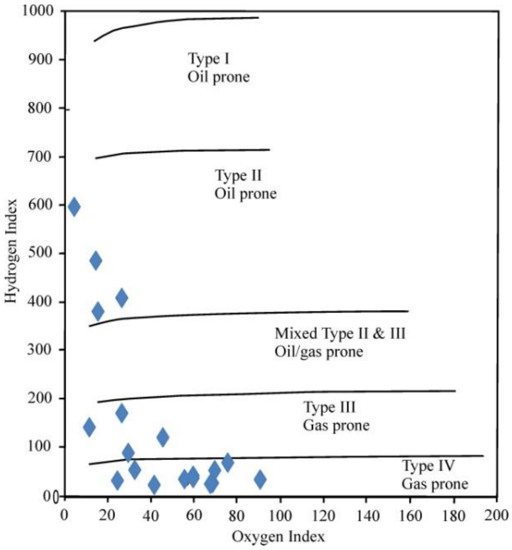

Figure 4: OI versus HI displaying type of hydrocarbon of the analysed Tura samples.

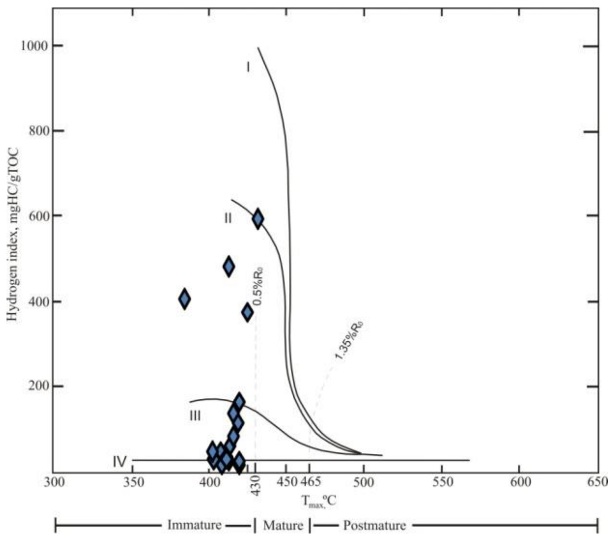

Figure 5: HI verus Tmax displaying type of kerogen and thermal maturity of the analysed Tura samples.

Theramal Alteration Index (TAI)

All study samples of the Tura sediments have grey to brownish in colour of amorphous organic matter i.e. sapropelic to charcoal facies, sapropelic-semifusinitic facies and charcoal facies (Figure 6). The amorphous organic matter has grey to brownish colour and has 19 to 82% (average 38%). The biodegraded terrestrial matter ranges from 3-30% while the charcoal is 1-28%. The semifusinitic organic matter ranges from 3 to 45%. However, all type of oraganic matter of charcoal, semifusinite, biodegraded terrestrial organic matters are well distributed in all samples. The most of Tura samples of TAI values ranges 1.0 to 3.0 of palynofossils. The maturity of OM of the Tura Formation indicates immature to mature state. The TAI values suggest good potential for generation of hydrocarbons. The most of Tura samples indicates potential source rock of hydrocarbon for oil and gas.

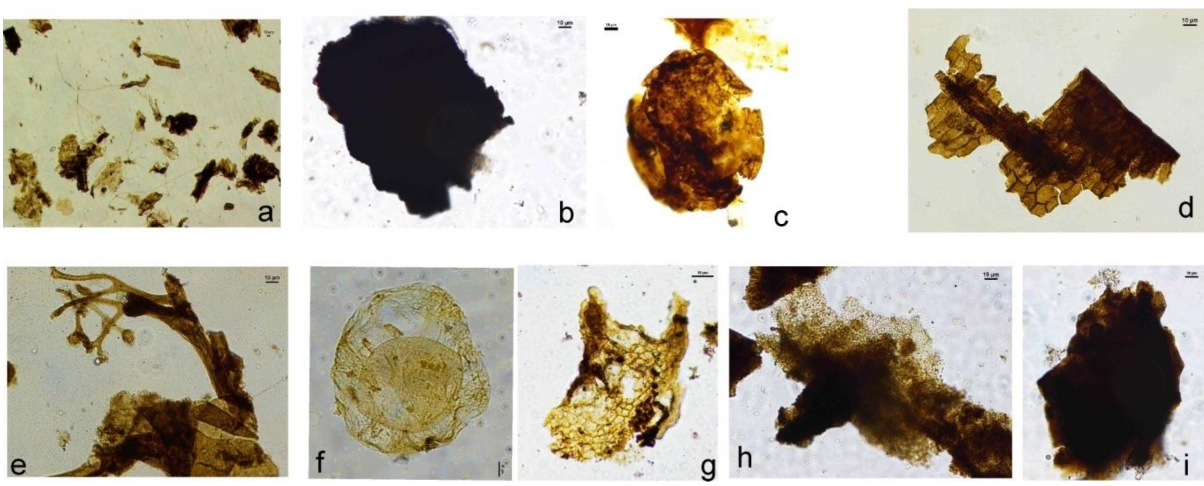

Figure 6: a). Humic-sapropelic-characoal facies with 1.5-3.0 TAI value b). Charcoal c). Pollen grain showing 3.0 TAI d, g). Partly biodegraded terrestrial organic matter e) Fungal remain f) Dinocyst showing 2.5 TAI h) Humic-sapropelic amorphous organic matter i) Semifusinitic organic matter.

Conclusions

A rich of palynological assemblage has been recorded from the Tura Formation and comprising of dinoflagellate cysts, spores and pollen grains, fungal remains and microforaminiferal lining. The palynoflora documented from the different traverse of sections in the Tura Formation of Garo Hills, Meghalaya has been assigned as late Paleocene to early Eocene in age. The occurrences of these palynofossils in the present study imply that freshwater/terrestrial environment (SW4, TG, TD, DS1, SW2) and shallow marine depositional environment (HG, TB1, BS1, BS2 7 DP) and warm, humid tropical-subtropical climatic conditions prevailed during course of sedimentation of the Tura Formation. The analysis of Rock Eval data and organic matters from the Tura shales has shown that all samples have poor to rich in richness and indicates a good souce rock potential for hydrocarbon generation.

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Table 1: Rock Eval parameter from the Tura Formation, Garo Hills (SW4, TD,TG, TB1, DP a represent sections).

Sample name	TOC (%)	S1 (mgHC/g Rock)	S2 (mgHC/g Rock)	S3 MgHC/g Rock)	T_{max} (ºC)	HI (mgHC/g Rock)	OI (mgHC/g Rock)	MINC (%)	PI	PO =S1+S2	Richness	Hydrocarbon type S2/S3
SW4-2	2.62	0.3	3.74	0.28	416	143	11	0.15	0.07	4.04	Fair	13.36
SW4-4	64.98	14.01	316.15	8.84	413	487	14	1.12	0.04	330.16	Rich	35.92
SW4-5	4.6	0.78	17.56	0.69	425	382	15	1.13	0.04	17.64	Rich	25.45
SW4-7	23.36	5.45	139.71	0.99	432	598	4	0.2	0.04	145.16	Rich	141.12
TD-1	0.68	0.02	0.24	0.61	413	35	90	0.09	0.08	0.26	Poor	0.39
TD-2	2	0.24	0.57	1.36	408	28	68	0.22	0.3	0.81	Poor	0.42
TD-3	1.76	0.08	0.96	0.57	408	55	32	0.1	0.07	1.04	Poor	1.68

TD-4	1.89	0.22	0.49	1.27	409	26	67	0.16	0.31	0.76	Poor	0.39
TD-5	1.48	0.06	0.54	0.81	404	36	55	0.22	0.1	0.6	Poor	0.67
TD-8	0.33	0.18	7.05	7.52	414	70	75	0.33	0.03	7.23	Good	0.94
TG-2	0.49	0.04	0.21	0.29	412	43	59	0.1	0.17	0.25	Poor	0.72
TG-5	0.66	0.03	0.25	0.39	412	38	59	0.1	0.12	0.28	Poor	0.64
TG-7	0.52	0.06	0.28	0.36	403	54	69	0.12	0.17	0.34	Poor	0.78
TB1-5	6.7	0.54	11.54	1.72	420	172	26	0.33	0.04	12.8	Rich	6.70
TB1-3	4.62	0.31	4.14	1.36	416	90	29	0.19	0.07	4.45	Fair	3.04
TB1-1	3.65	0.23	4.47	1.66	419	122	45	0.37	0.05	4.7	Fair	2.69
DP3	2.59	0.1	0.63	1.05	420	24	41	0.28	0.14	0.73	Poor	0.6
DP5	2.24	0.16	0.73	0.53	420	33	24	0.27	0.18	0.89	Poor	1.37
BS2-3	34.89	11.13	143.14	9.16	385	410	26	0.71	0.07	154.27	Rich	15.62