

## Field guide to the geological evolution of the Maastrichtian rocks of the Central Inlier, Jamaica

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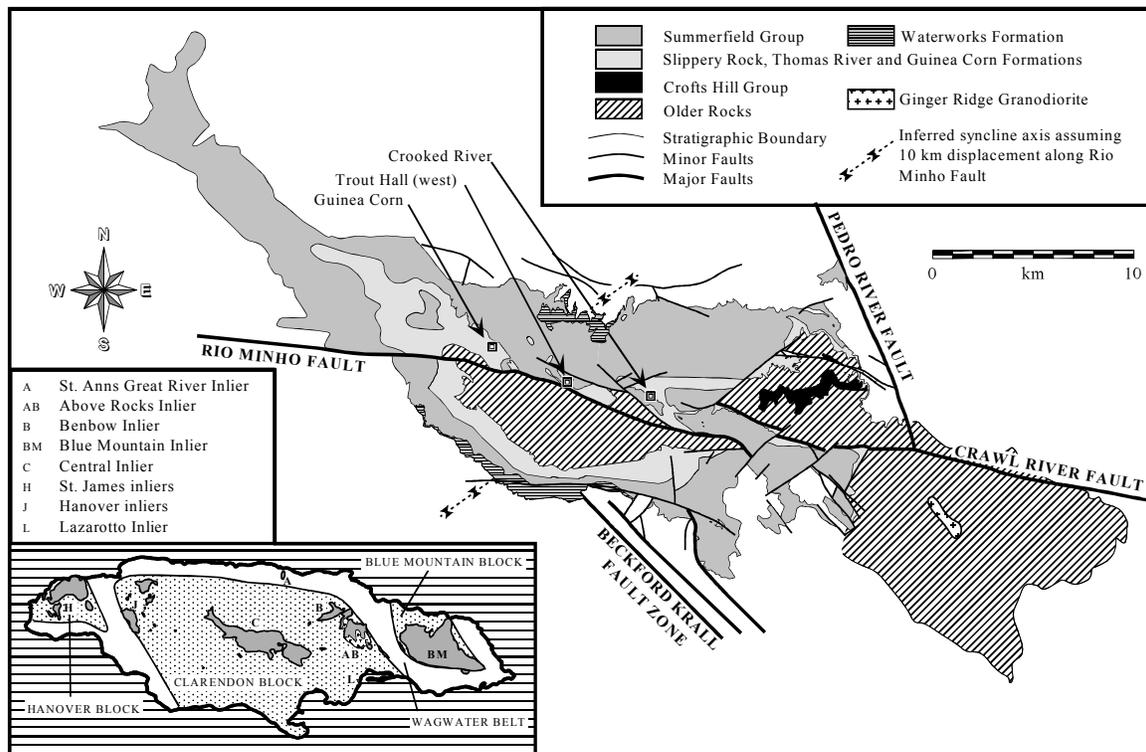
**ABSTRACT.** This field guide describes the geology found in the central part of the Central Inlier. The oldest rocks present, the Arthurs Seat Formation represent the deposits of a volcanic arc. These are succeeded unconformably by a Maastrichtian (Upper Cretaceous) transgressive-regressive cycle consisting of the Slippery Rock, Thomas River and Guinea Corn formations, and the Summerfield Group. The various stops show how this transgressive-regressive cycle developed.

### INTRODUCTION: GEOLOGY OF JAMAICA

The geological history of Jamaica is conveniently divided into four phases (Draper, 1990, 1998). These are: 1) a Cretaceous island arc phase; 2) a Paleocene to Early Eocene phase of rifting of the arc system; 3) Middle Eocene to Miocene deposition of carbonate platform deposits; and 4) Late Cenozoic deformation leading to major uplift and mountain building. The Cretaceous island-arc phase contains rocks ranging in age from

Hauterivian to Maastrichtian. The Maastrichtian rocks of the Central Inlier, which are considered in this field guide, were deposited as a major transgressive-regressive cycle, and illustrate the interrelationships between marine carbonate deposition and active island arc volcanoclastic sedimentation.

This field guide is based on very successful field trips by the Geological Society of Jamaica (a record 43 members and friends) and the Universities of East Anglia and Edinburgh.



**Figure 1.** Summary geological map of the Central Inlier showing principal stratigraphic units and major structural features. Inset, distribution of main Cretaceous inliers and the structural blocks and troughs of Jamaica.

THE CENTRAL INLIER

The Central Inlier is the second largest inlier (the Blue Mountains Inlier is the largest) exposing Cretaceous rocks in Jamaica (Fig. 1). It is largely drained by the Rio Minho and its tributaries, which have cut down deeply into the Cretaceous succession. Although the geology of the Central Inlier has been known in a general sense ever since the early studies of geology in Jamaica (e.g., De la Beche, 1827; Sawkins, 1869; Hill, 1899; Trechmann, 1924), a real understanding of the succession was only achieved in the nineteen fifties

and sixties through the mapping of the Jamaican Geological Survey (reported by Williams, 1959a, b and Coates, 1964, 1965, 1968). These studies largely divided the succession into alternating fossiliferous beds, which attracted great attention, and thick intervening clastics, volcanoclastics and igneous units, which were invariably undivided and attracted little or no interest. The fossiliferous, predominantly carbonate sediments were heavily studied, particularly with regard to the rudist bivalves, the most conspicuous fossils that they contained, and Jamaica became the Mecca for Caribbean rudist workers (e.g., Chubb, 1971;

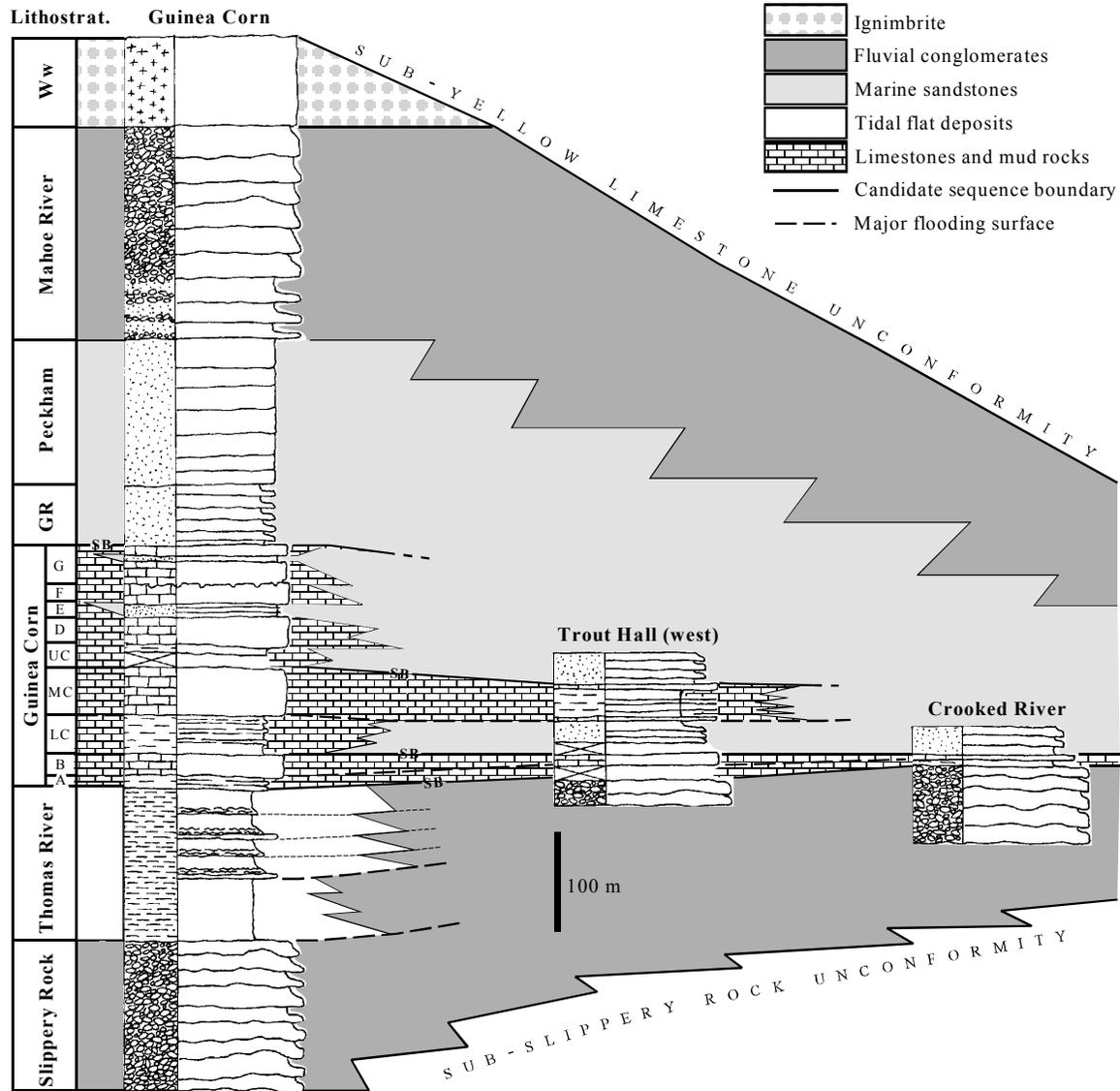


Figure 2. Summary stratigraphy of Maastrichtian rocks in Central Inlier (See Fig. 1 for location of sections). The succession represents a transgressive-regressive cycle, the wedge-shaped geometry of the marine deposits is obvious in this figure. A-G, bed letters of Mitchell, 1999.

Kauffman and Sohl, 1974; Kauffman and Johnson, 1988). Despite the wealth of work on the rudists, some interest was maintained on the volcanoclastics (e.g., Roobol, 1976) and the igneous rocks (e.g., Jackson, 1987).

Recent work (Mitchell and Blissett, 1999, 2001; Mitchell, 1999, 2000, in press) has led to a much fuller understanding of the sedimentary successions present and their relationship to the Cretaceous island arc system.

### STRATIGRAPHY

The succession examined consists of a major Maastrichtian (Late Cretaceous) transgressive-regressive cycle that was deposited in a back-arc basin situated at some distance (perhaps 50 km) from the arc volcanoes. The stratigraphy is described below (Fig. 2).

#### Arthurs Seat Formation

The name Arthurs Seat Formation is now applied to the rocks of Main Ridge formerly called the Main Ridge Formation (Mitchell, in press). The Arthurs Seat Formation consists of a thick succession of largely unbedded poorly sorted conglomerates. The clasts mainly consist of andesitic lithic fragments and crystals, although other lithologies are also present. The succession contains many andesitic and less frequently amygdaloidal basaltic lava flows and is intruded by a variety of dykes (hornblende and pyroxene andesites, amongst others). The formation is currently being mined for gold.

Fresh exposures of the Arthurs Seat Formation in rivers may be extremely hard, elsewhere deep tropical weathering has altered the primary igneous minerals to clays and locally intense leaching, particularly on ridges, has produced bauxitic soils.

The Arthurs Seat Formation represents the deeply eroded remnants of an early island arc system, the presence of dykes in the Arthurs Seat Formation and their lack in the overlying post-Arthurs Seat sediments indicating the significant erosion and time gap that exists between the two successions.

#### Slippery Rock Formation

The name Slippery Rock Formation was introduced by Robinson and Lewis (*in Robinson et al.*, 1972) for the conglomerates, sandstones and siltstones

exposed along the road to the north of the Slippery Rock River. The name was restricted to the conglomerates and interbedded sandstones and mudstones by Mitchell and Blissett (2001), the overlying thick mudstone succession being called the Thomas River Formation.

The Slippery Rock Formation is a thick succession of conglomerates and minor interbedded sandstones. The lowermost part consists of very poorly-sorted, matrix-supported, unstratified conglomerates and interbedded clast-supported imbricate conglomerates and sandstones. The matrix-supported, unsorted conglomerates are interpreted as debris flow deposits, the clast-supported conglomerates and sandstones, as braided stream deposits.

The lower part of the Slippery Rock Formation passes rapidly upwards into a succession of erosively based conglomerates with imbricate clasts and trough cross-bedding. These conglomerates show distinctive 1-4 m thick rhythms. The basal part of these rhythms is composed of clast-supported conglomerates with strongly erosive bases. This passes upwards into muddy, pebbly sandstones that have insipient to well-developed nodular calcretes. Locally, the nodular calcretes preferentially cement burrow systems or root structures. The calcretes and cemented burrow systems are variably truncated by the base of the overlying rhythm. The rhythms are interpreted as braided stream channel deposits, with soil (calcrete) horizons developed adjacent to channels and burrows probably formed by land crabs.

The uppermost part of the Slippery Rock Formation is characterised by poorly-sorted pebbly sandstones with localised pebble stringers alternating with 10-20 cm thick laminated sandstone beds. The former are interpreted as braided stream deposits, the latter, as sheet-flood deposits.

The facies represented in the Slippery Rock Formation, namely braided stream/debris flow deposits – braided stream deposits – braided stream/sheet flood deposits indicates that this represents an alluvial fan system. The former interpreted as proximal facies the latter as distal.

In the western part of the Central Inlier the uppermost sandstones and conglomerates of the Slippery Rock Formation contain scattered marine fossils (bivalves and gastropods) and trace fossils (*Arenocolites* isp. and *Taenidium serpentinum* Heer). This marine influx is succeeded by a thick series of red and grey shales with minor sandstones and limestones (Thomas River Formation). In the mid Central Inlier the Slippery Rock Formation is succeeded by the Guinea Corn Formation.

### Thomas River Formation

Williams (1959a, b) recognised 500 ft of shales, which he placed either, at the base of Rudist Limestone (Williams, 1959a, p. 256) or, in the upper part of the Lower Tuffaceous Series (Williams, 1959b, p. 12). ‘Williams’ shale unit’ consists of a thick succession of red and grey mudstones that contain thin ripple cross-laminated sandstones and was named the Thomas River Formation by Mitchell and Blissett (2001). The lower part of the formation is characterised by monotonous red siltstones with thin layers of concretionary limestones which are interpreted as calcretes. The red mudstones are mainly massive, but in the upper levels contain thin intervals of grey mudstone and thin ripple cross-laminated siltstones and sandstones. Some of the sandstones contain disarticulated valves of the small bivalve *Perucardium* sp. which are orientated convex-side up. Some mudstone layers also contain sand-filled desiccation cracks.

The red mudstones are succeeded by grey mudstones which contain more frequent ripple cross-laminated sandstones showing bi-directional palaeocurrents and stacked flaser-wavy-lenticular bedded units. The fauna of the grey mudstones is more varied than the underlying red mudstones. The bulk of the fauna is characterised by the same low diversity *Perucardium* fauna, but also includes micromorphic gastropods, abundant fresh to brackish water algae (charophytes: see Kumar and Grambast-Fessard, 1984) and rare low diversity ostracod and smaller foraminifera assemblages. Some layers contain a more diverse fauna including actaeonellid gastropods (*Actaeonella granthamensis* Sohl & Kollman), rare corals, a few rudists (*Bournonia cancellata* (Whitfield) and ‘*Antilocaprina*’ *stellata* Chubb) and diverse ostracods, indicating more open marine conditions.

The sedimentary structures (flaser, wavy and lenticular bedding, bi-directional ripple-cross lamination, desiccation cracks, and convex upward disarticulated bivalves), together with the abundance of the brackish to fresh water fauna (*Perucardium*, small oysters, charophytes, low diversity micromorphic gastropods) suggests that this unit can be interpreted as an estuary (or fresh-water fed tidal lagoon system) containing extensive tidally influenced mudflats. Brackish to fresh water conditions prevailed (as evidenced by the charophytes), but marine flooding of the estuary resulted in the introduction of a marine fauna (rudists and corals) at several levels.

### Guinea Corn Formation

The name Guinea Corn Limestone was first used by Chubb (*in Zans et al.*, 1963) for the limestones in the upper part of the Titanosarcolites Series in the Central Inlier. Coates (1965) described a new section in the Guinea Corn Formation exposed in Pindars River near the town of Crawle River and defined a type locality for the Guinea Corn Formation at Grantham. Mitchell (1999) accepted this as the type locality and indicated a thickness of 140 to 165 m for the formation around Grantham.

The boundary between the Thomas River Formation and the Guinea Corn Formation is sharp and represents a significant palaeoenvironmental change. Elsewhere the Guinea Corn Formation rests sharply on the Slippery Rock Formation.

The Guinea Corn Formation is particularly well-known for its rudist bivalve assemblages, and many species are abundant (Chubb, 1971).

### Summerfield Group

The Summerfield Group represents an important episode of andesitic volcanism in the Caribbean (Coates, 1968; Roobol, 1976; Jackson, 1987). Coates (1968, p. 313) formally introduced the name Summerfield Formation (previously used as ‘Summerfield volcanoclastics’ by Coates, 1965, fig. 1) for the Upper Tuffaceous Series of Williams (1959a, b) and stated that the Summerfield Formation “had been mapped as two separate horizons,” a lower part consisting of regularly bedded volcanic grits and sandstones and an upper part consisting of thick bedded volcanic conglomerates. Roobol (1976) studied the Summerfield Formation and recorded the succession in the Rio Minho and along the road from Guinea Corn to Johns Hall, assuming this to represent a relatively continuous section with only minor faulting.

Mitchell and Blissett (2001) raised the status to group and named four formations in the Summerfield Group. The Green River Formation (19-31 m thick) consists of thinly-bedded, normally-graded sandstones in beds from 10 to 40 cm thick, interbedded with mud rocks. The boundary is diachronous and Green River Formation-like lithologies interdigitate with the upper part of the Guinea Corn Formation. The Peckham Formation (75-150 m thick) consists of thickly bedded sandstones in beds, typically 80 cm to 4 m thick. Internally the sandstones show massive, amalgamated normally-graded beds, or exhibit

parallel lamination and soft-sediment deformation features. The transition from the Green River to Peckham Formation is abrupt, with a dramatic change from thinly bedded sandstones to thickly bedded sandstones. The Mahoe River Formation (190-200 m thick) is represented by clast- and matrix-support conglomerates, which consist of rounded andesite and rare ignimbrite clasts up to 50 cm in diameter in a sandstone matrix. The beds are thick to very thick (0.8 m to 5 m). There is a more gradual transition from the Peckham Formation to the Mahoe River Formation, the boundary being taken at the first prominent conglomerate layer. The lower part of the Mahoe River Formation therefore consists of interbedded sandstones and conglomerates. The Waterworks Formation (up to 75 m thick) is an ignimbrite which contains scattered hornblende needles, angular clasts of red shale, and weakly flattened pumice fragments. The lower part has some andesite clasts. With the exception of the lower part, the Waterworks Formation is massive. The lower part may show cross-bedding with large-scale ripples, dunes and ?antidunes, which are interpreted as a surge deposit at the base of the flow. The ignimbrite shows characteristic core-stone weathering and alteration to terra rossa along ridges.

Mitchell (2000) interpreted the Summerfield Group as a volcanoclastic braid-delta that build out from an active volcano. The Green River and Peckham formations represent the marine delta front deposits and the Mahoe River the delta top deposits. The Waterworks Formation represents a thick succession of ignimbrites.

### STOP 1. SLIPPERY ROCK FORMATION

At Pennants (Fig. 3), take a southerly turn at 'God Father Bar', taking the immediate left track which climbs up above the sports field. After about 200 m take a right turn, and a further left turn some 300 m further on. This carries you over a small bridge and up a hill; at the hill crest turn right. Various paths lead down to the Thomas River from this road. The upper part of the Slippery Rock Formation is exposed in an excellent section on a bend in the Thomas River near Pennants (Fig. 3). Watch out for quicksand in wet weather.

A measured section of more than 27 m is shown in Figure 4. The lower part of the succession consists of sheet-like conglomerates and pebbly sandstones that contain extensive trough cross-bedding. The intervening, poorly-sorted, pebbly sandstones contain scattered calcrete horizons and rare burrows assigned to *Thalassinoides* isp. The

pebbles are rounded to subrounded.

The lower pebble-dominated succession is succeeded by poorly sorted mud rocks with scattered pebbles and occasional parallel-laminated fine-grained sandstones (Fig. 4). Calcrete horizons are developed in some of the pebbly mud rocks.

The trough cross-bedded pebbly sandstones and conglomerates can be interpreted as channel deposits formed by the migration of coarse grained (sand and pebble) dunes within braided river channels. The intervening units with their calcrete horizons and burrows are interpreted as soil horizons (calcretes) formed between active channels. Such coarse grained sediments are interpreted as braided stream deposits and associated interchannel soil horizons on the medial portion of an alluvial fan system.

The red or reddish-brown colouration of such deposits, means that they are often called 'red bed successions'. The calcrete horizons suggest semiarid conditions, which are favourable for the development of extensive alluvial fan systems.

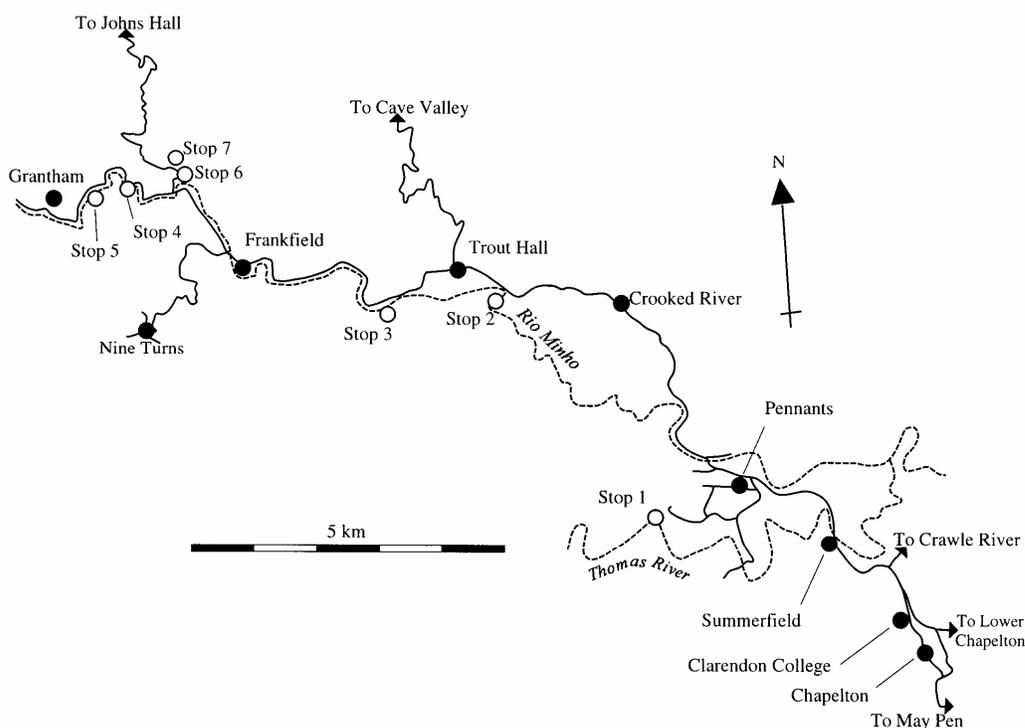
The upper part of the Pennants section is interpreted as background sedimentation (pebbly mudrocks with calcretes – i.e., soils) alternating with infrequent sheet flood sands. Such an facies suite occurring above the coarser grained braided stream facies suggests a more distal setting, probably flanking the open ocean, and having a lower gradient.

This section is an excellent locality for looking at provenance of sediments. A quick survey of the pebbles present indicates a great variety. Included are various andesites, basalts, sandstones, micritic limestones and even rare agates! This testifies to the mature geological landscape that was being eroded by the alluvial fan systems that formed the Slippery Rock Formation.

### STOP 2. ARTHURS SEAT FORMATION

Return to the main Chapelton-Trout Hall road, and proceed westwards through Crooked River. As the flood plain of the Rio Minho opens out, about 1 km beyond Crooked River, park in a convenient spot (a suitable spot is on the right hand side of the road where there are bars on both sides of the road). The Rio Minho flows on the south side of the road and passes into a steep-sided gorge. The Trout Hall end of the gorge is formed by a succession of intensely hard volcanoclastic siltstones and fine grained sandstones, which have well-developed parallel lamination. A typical small andesite dyke is also present.

Ford the river and walk down stream about 200 m. BE CAREFUL OF THE THORN BUSHES.



**Figure 3. Geographical locations of stops 1 to 7. Roads, solid lines; rivers, dashed lines**

A good dyke is exposed beneath a Tamarind tree. The dyke contains abundant very large crystals of black hornblende, together with smaller phenocrysts of white plagioclase. The hornblende crystals may be easily identified by their basal sections which have six sides (pyroxenes have eight). Thin section analysis suggest an andesitic composition for this dyke.

The Arthurs Seat Formation consists of a diverse suite of sedimentary and igneous rocks, including: unstratified, poorly sorted conglomerates; laminated volcanoclastic siltstones and sandstones, andesitic and basaltic lavas and a variety of dykes. The hornblende andesite dyke at this stop is a particularly fine example.

The Arthurs Seat Formation is overlain directly by the Slippery Rock Formation. The significant differences between the two formations include: (i) the Arthurs Seat Formation is intensely hard in unweathered sections, while the Slippery Rock Formation is remarkably un lithified; (ii) the conglomerates in the Arthurs Seat Formation are exclusively composed of andesite, while those in the Slippery Rock Formation are composed of numerous different clast types; and (iii) the Arthurs Seat Formation is intruded by numerous dykes, while the Slippery Rock Formation contains no dykes.

Taken together, this indicates that the Arthurs Seat Formation represents a older suite of rocks that was uplifted and deeply eroded prior to the deposition of the Slippery Rock Formation.

### STOP 3. VOLCANICLASTIC SANDSTONES IN THE GUINEA CORN FORMATION

After returning to the main road, take the road through Trout Hall towards Frankfield. About 100 m before the partially collapsed railway bridge, park at the 'fording' across the Rio Minho (where locals wash their cars).

Here volcanoclastic sandstones in the Guinea Corn Formation are beautifully exposed in the middle of the river (Fig. 5). The beds are vertical (due to the proximity of the Rio Minho Fault), and offer an excellent opportunity to use sedimentary structures as way up indicators.

This exposure shows facies typical of the sandstones/mudstones interbedded with the limestones in the upper part of the Guinea Corn Formation and the lower part (Green River Formation) of the Summerfield Group, together with a variety of other sedimentary structures. The succession consists of parallel bedded sandstones and intervening mudstones.

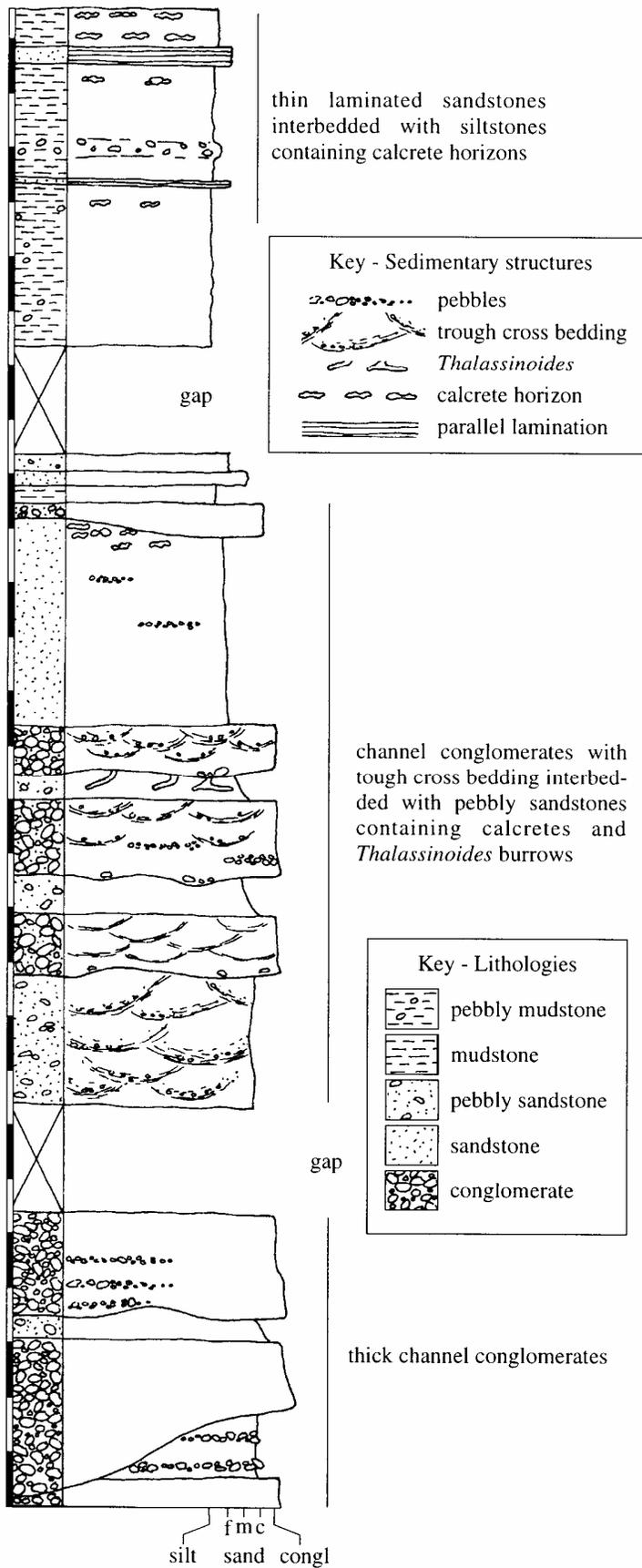


Figure 4. Graphic log showing the succession in the Slippery Rock Formation at the bend in the Thomas River at Pennants. Scale bar in metre intervals.

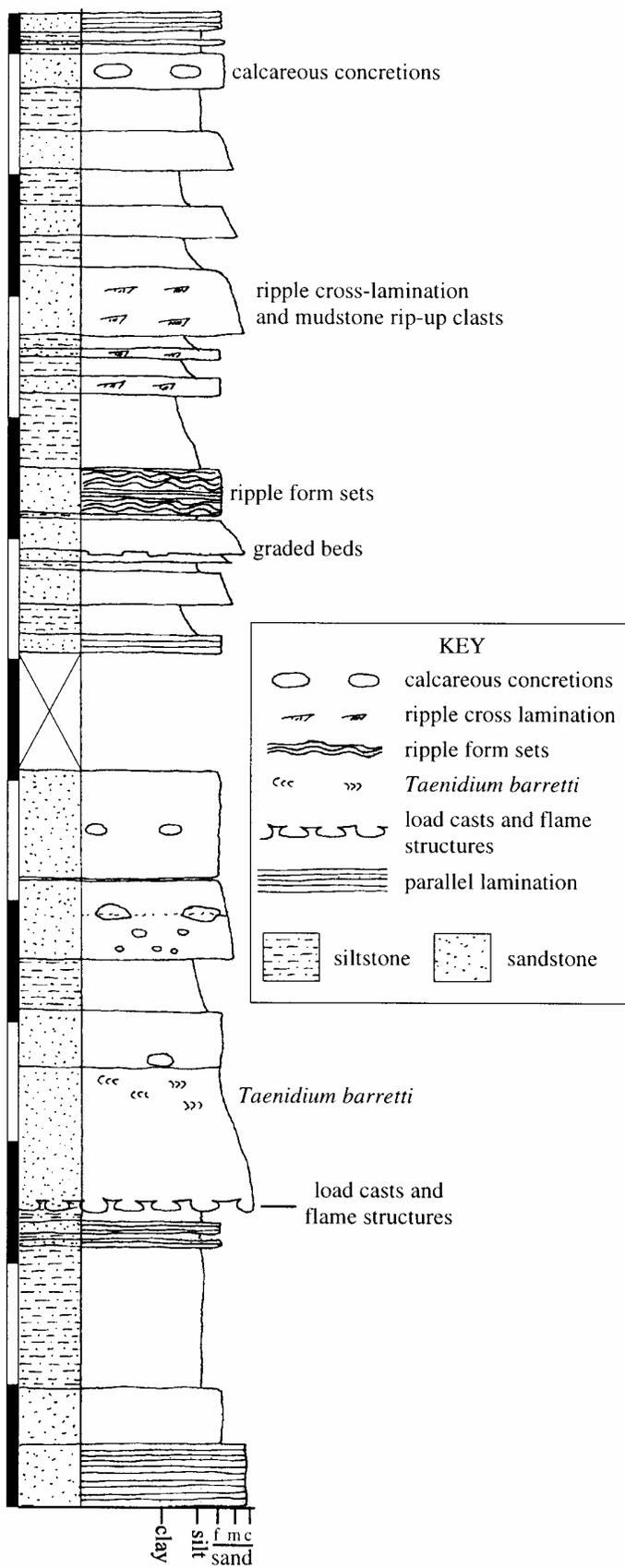


Figure 5. Graphic log showing volcaniclastic sandstones in the Guinea Corn Formation in the Rio Minho near Trout Hall. Scale bar in metre intervals.

The lower part of the succession contains a very prominent thick sandstone bed, the base of which has load casts and flame structures. The upper part of the same bed contains rare examples of rudist bivalves (PLEASE DO NOT REMOVE) and the trace fossil *Taenidium barretti* (Bradshaw). The latter has only previously been reported (Keighly and Pickerill, 1994) from terrestrial deposits, and its occurrence in Jamaica associated with rudist bivalves is worthy of note.

Higher levels in the succession reveal further points of interest: (i) pumice pebbles in sandstones; (ii) ripple cross-laminated sandstones, (iii) ripple form sets; (iv) normally graded sandstone units; and (v) erosively based units.

The impressive hills to the south of the river are composed of the Arthurs Seat Formation. A nice variety of loose material is carried into the Rio Minho by small streams and good rock specimens can be picked up (andesites and tuffaceous conglomerates).

#### STOP 4. LUNCH. THE RIO MINHO AT CABBAGE HILL

Drive on through Frankfield and take the road to Grantham. At Cabbage Hill the Guinea Corn Formation is very well exposed, and is a classic site much visited by geologists. Lunch can be taken here, and there is also an opportunity to look at the Guinea Corn succession. Points of note include the following:

A band rich in oncoids. Oncoids are algal balls secreted around a nucleus, in this case a fragment of coral. Some of the concentric layers show evidence of boring. Since algae photosynthesise, the abundance of algae indicates deposition within the photic zone.

The *Praebarrettia* bed yields common examples of the large rudists *Praebarrettia sparcilirata* (Whitfield) (Fig. 6) and *Macgillavryia nicholasi* (Whitfield) in a matrix rich in volcanicalstic debris.

Unit E (Mitchell 1999) of the Guinea Corn Formation is also well-exposed. The basal 1.8 m is represented by thinly bedded graded sandstone units, the upper part contains thicker volcanicalstic graded units.

The *Macgillavryia* bed yields numerous examples of the large rudist *M. nicholasi* together with many other rudists including *Chiapasella* sp., *Titanosarcolites giganteus* (Whitfield), *Biradiolites jamaicensis* Trechmann and *Plagioptychus* sp. (Fig. 6).

#### STOP 5. THOMAS RIVER FORMATION

After lunch drive on to a small exposure in the Rio Minho near Grantham (Fig. 3). Here some sandstones in the Thomas River Formation are well exposed (Fig. 7).

The succession consists of stacked small rhythms which show a progradation from flaser bedding through wavy bedded units to lenticular beds. Flaser bedding consists predominantly of ripple cross-laminated sandstone with small mudstone flasers; wavy bedding is an equal mix of mudstone and ripple cross-laminated sandstone; lenticular bedding consists of isolated sandstones lenses containing ripple cross-lamination within mudstone. Careful examination of the ripple cross-lamination demonstrates that ripple migration was bi-directional. Stacked flaser-wavy-lenticular bedding rhythms with bi-directional palaeocurrents are typical of tidal flat sequences.

The base and top of the sandstone unit are represented by fossiliferous beds, which yield low diversity assemblages of oysters and a few small infaunal bivalves.

The overlying and underlying mudstones contain rare small gastropods and examples of gyrogonite charophytes which indicate fresh or brackish water conditions. Plant debris is abundant and the rock splits along surfaces due to its abundance.

The low diversity faunal assemblages, the abundant plant material, and the tidal flat sequences, suggest that the succession accumulated in an estuary.

#### STOP 6. CONGLOMERATES IN THE SUMMERFIELD FORMATION

Return back along the road towards Frankfield, and take the north-bound road that leads up to Johns Hall. This road shows repeated sections through the conglomerates of the Mahoe River Formation, and these are well-exposed in the first bend on the road. The conglomerates are poorly stratified, some are poorly sorted while others show clast imbrication. This indicates that deposition was by alternating fluvial and debris flow processes.

Although a similar environment to the conglomerates in the Slippery Rock Formation, the major difference is in the clast types. The Slippery Rock Formation contains a great variety of different clasts, the conglomerates of the Summerfield Group only contain igneous clasts of andesitic to dacitic composition.

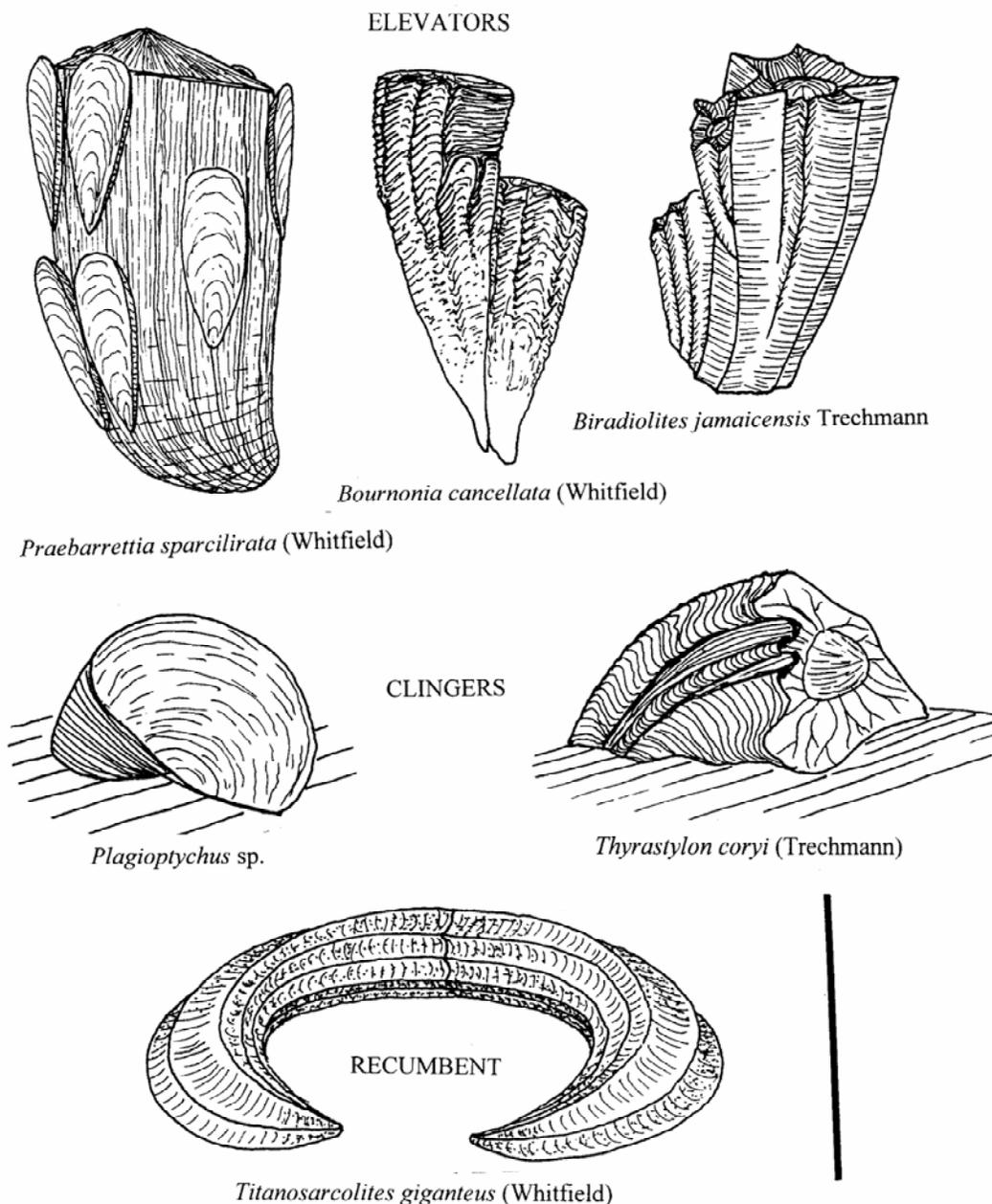
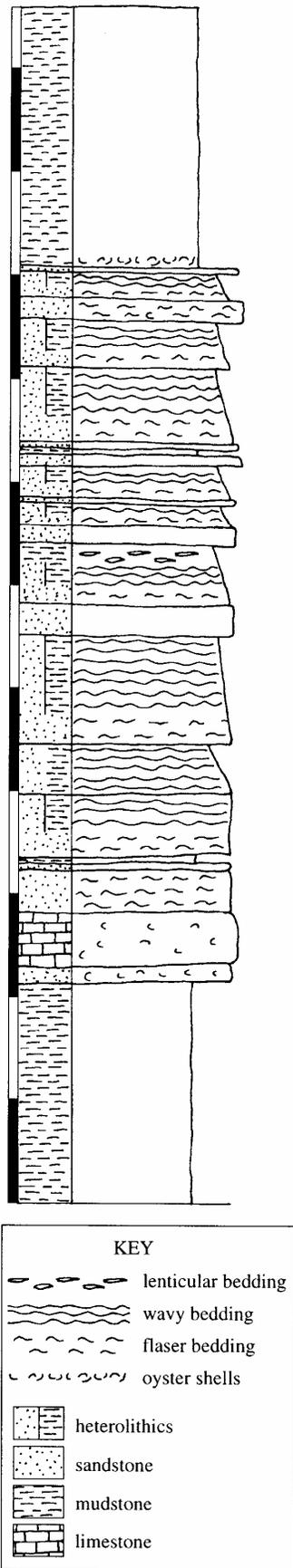


Figure 6. Examples of rudists found in the Guinea Corn Formation at Cabbage Hill. Scale bar is 5 cm for all rudists except *Praebarrettia* (=20 cm) and *Titanosarcolithes* (= 1 m)

**STOP 7. IGNIMBRITE**

Continue further up the road towards Johns Hall and take the track that leads off to the right. The bank of this track shows sections in the ignimbrites of the Waterworks Formation. Pumice and red shale fragments are common, together with numerous crystals (plagioclase, hornblende and apatite). Ignimbrite deposits are formed from

hot pyroclastic flows that contain ash, crystals and pumice. The eruption of Mount St. Helens was a recent, although small, example. This ignimbrite terminates the Cretaceous (or possibly Paleocene) succession, and the sedimentary rocks and ignimbrite of the Summerfield Group are overlain unconformably by the Yellow Limestone Group of Early to Middle Eocene age.



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**Figure 7. Graphic log showing the Thomas River Formation at Grantham. Scale bar in metre intervals**

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