The Upper Silurian of Touat (Algerian Sahara) and its fauna

PHILIPPE LEGRAND

In the Touat region (Algerian Sahara), the most complete Palaeozoic succession occurs to the southwest of Adrar. In the Tamest section, the Silurian comprises the Fenourine Clay and the Touat Sandstone formations. The Fenourine Clay Formation consists mostly of silty claystones of which only the upper 150 m crop out. At the base of the section, bivalves occur, followed by the graptolites *Saetograptus chimaera* aff. *salweyi* (Hopkinson) and *Pristiograptus* cf. *P. tumescens minor* (Wood) which are described and figured in this paper. The overlying Touat Sandstone Formation is 170 m thick. It comprises silty claystones with several lenticular, sandy beds, surmounted by a sandy, calcareous bed. At the base of the sandstone, pieces of homalonotine trilobites, brachiopods and bivalves are present. Above the base, silty claystones, a ferrugineous siltstone bed and the first Tentaculoidea occur. A conglomeratic limestone bed yielding a Pragian fauna tops the formation. The ages are as follows: the lower and middle Silurian do not crop out. The graptolites at the base of the extant section belong to the associations σ3β which characterize the Saharan Ludlow Series (g3b) (Legrand 1981, 1985). The silty, clayey beds that follow may be the equivalent of the Přídolí (g3c). The fossiliferous beds at the base of the Touat Sandstone may also be of Přídolí age, or may indicate the base of the Lochkovian (g4c). These outcrops reveal an interesting evolution in terms of facies and faunal assemblages towards the Ougarta Mountains and the Gourara to the northwest and the Azzel Matti to the southeast. • Key words: Algerian Sahara, Touat, Silurian, graptolites, bivalves.

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In the Touat region of the Algerian Sahara, the most complete Palaeozoic succession is located to the southwest of Adrar (Fig. 1). However, strata of "Continental Intercalaire" (Cretaceous), Mio-Pliocene and Quaternary age overlie the lower and middle Silurian and part of the Famennian. The beds dip regularly to the southwest, and belong to the eastern limb of a broad asymmetrical syncline, the other limb of which crops out in the eastern extremity of the Eglabs.

The significance of these outcrops lies in the fact that they are situated halfway between the southern end of the Ougarta Mountains (Djebel Hèche Section, Gourara) and the northernmost outcrops of Azzel Matti (Aïn ech Cheikr Section) (Fig. 1).

From a structural viewpoint (Legrand 1985), the Palaeozoic outcrops are to the south of the intersection of two major Saharan platform trends: the W-E trend of the northern border of the Eglabs, which is probably the oldest (Early Proterozoic); the NW-SE trend of the Ougarta Mountains of pan-African age (Late Proterozoic). However, the present outcrops show yet the trend NW-SE and not the N-S trend shown by the Reggane belt, also of pan-African age, which is often considered as following on the previous one.

Historical background

The Palaeozoic outcrops of Touat were first reported by Gautier (1908), but Meyendorff (1939) deserves the credit for clearly indicating the occurrence of Silurian strata, although without recording any palaeontological evidence. Meyendorff attributed to the Silurian the "argillaceous and sandy shales interbedded with limestones with fragments of Cardioles and Orthoceras". According to him, the Lower Devonian began with the sandy shales with pieces of the trilobite *Homalonotus* and rhynchonellid brachiopods. Probably, these are the same beds the brachiopod fauna of which is mentioned below.

The beginning of oil exploration next saw the Palaeozoic outcrops studied [by, among others, Compagnie Française des Pétroles (Algérie), 1953 and Bureau des Recherches Pétrolières, 1954]. A section was compiled by Burollet & Manderscheid and later published by Legrand (1962). A doubtful specimen of "*Monograptus*" *colonus* found in a broken sample again suggested the presence of the lower Ludlow. From the beds with small brachiopods, *Camarotoechia nucula* (Sowerby) and *C.* eg. *tarda* (Barrande) (identifications by D. le Maître) were listed. In 1968,

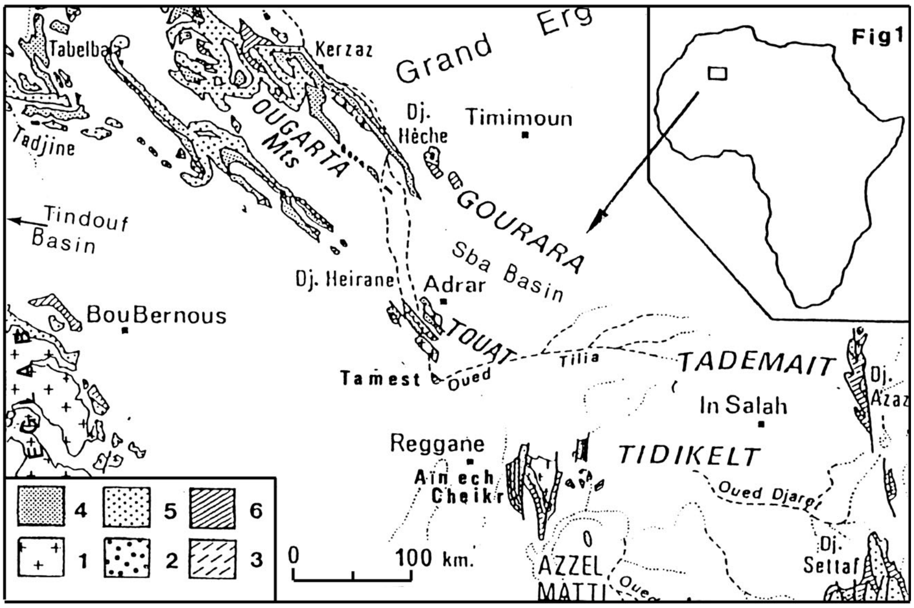


Figure 1. Location map of the study area. Lower Palaeozoic outcrops: 1 – Precambrian; 2 – lower Cambrian; 3 – uppermost Cambrian; 4 – Cambrian of Ougarta Mountains, Gourara, Touat, and Bled el Mass; 5 – Ordovician; 6 – Silurian (map from Legrand 1999).

these outcrops were re-examined by the author and later briefly described (Legrand 1985). An early Ludlow age for the first calcareous bed was confirmed and a Přídolí age proposed for the beds containing brachiopods (Legrand 1985).

Section description

The studied section (Figs 2, 3) is known as either the Tamest section, or Section at 10 km southwest of El Ahmar. The following lithostratigraphical units have been recognised:

The Fenourine Clay Formation (Legrand 1962, 1967, 1985). Only its upper part (about 150 m and not 200 m as previously measured) is visible, and this consists mainly of argillaceous siltstones with some interbedded calcareous sandstones, sandy limestones and fine-grained sandstone. The lower claystones have yielded the bivalves (identifications by C. Babin) *Butovicella* sp. and *Mytilarca* cf. *M. esuriens* (Barrande), while the lowest sandy-calcareous bed has yielded the graptolites *Saetograptus chimaera* aff. *S. salweyi* (Hopkinson) and *Pristiograptus* cf. *P. tumescens minor* (Wood), as well as the bivalve *Dualina* sp. and many scolecodonts. Further up in the section, besides many shells of "*Orthoceras*", a bed with the brachiopod *Hypselonetes*? sp. (identification by P.R. Racheboeuf) and pieces of homalonotine trilobites has been noted. All excavations in the upper part of the formation have revealed barren, silty clay.

The Touat Sandstone Formation (Legrand 1962, 1967, 1985). This is a thick (170 m) unit of silty claystones with interbedded sandstones and a prominent sandstone at the top. At the base are beds of beige- or greenish, fine to microconglomeratic sandstones with intercalated fossiliferous, amygdaloidal sandy limestone beds separated by silty claystones. Numerous bivalves were collected here: *Cypricardella* sp., *Phestia* sp., *Modiomorpha* sp., *Paleoneilo*? sp., *Nuculites* sp., *Grammysoidea* sp., *Myophoria* sp., *Leptodesma* sp. (identifications by C. Babin), as well as ostracods, gastropods, "*Orthoceras*" and rare Homalonotinae. Brachiopods are also abundant, but they have not been studied.

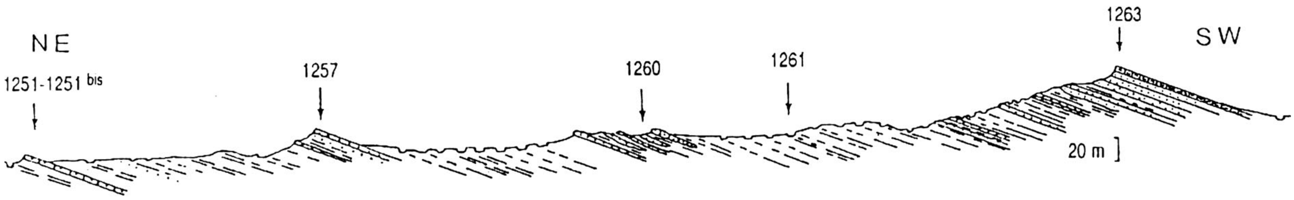
Above the silty claystones, partly covered by overburden, is the main argillo-ferruginous unit of siltstones with the first Tentaculoidea. Above the silty sandstones, beginning with a bed of ferruginous sandstone, the strata become progressively sandier terminating as irregularly stratified, fine- to medium-grained sandstones with sparse fossiliferous calcareous intercalations.

Biostratigraphical dating

As graptolites are rare in the Algerian Sahara, graptolite associations combining several graptolite biozones have been defined. In a similar way, regional stages and substages were defined later (Legrand 1981, 1985).

Graptolites from the lower sandy limestone of the Fenourine Clay Formation belong to the group of associations σ3β that characterizes the Ludlow of the Algerian Sahara. More precisely, they could belong to the association σ3β3 or σ3β2 that characterize the regional substages g3b3 or g3b2, which are equivalent to the upper or middle part of the lower Ludlow.

The very fossiliferous beds at the base of the Touat Sandstone Formation are postulated to be of Přídolí age (g3c). Above them, it is possible that the first level of ferruginous siltstone with Tentaculoidea is of Devonian, more precisely Lochkovian (g4) age, in a Gedinian facies.



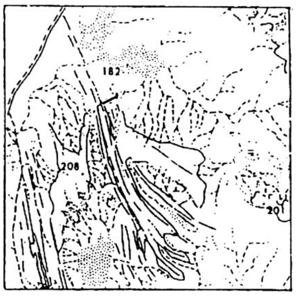


Figure 2. Tamest section. • A – position of the section (from the topographic map ADRAR, sheet NG-30-XXIV; x = 0°20′ 46″, y = 27°24′ 53″). • B – profile of the Tamest section (upper Silurian–lowermost Devonian; Legrand, January 1968, unpublished).

Earlier fossil lists (Legrand 1968) indicated a Pragian age for the upper part of the Touat Sandstone Formation.

Sedimentology and palaeoecology

Dark claystones occur only at the base of the section. They are interpreted as having been laid down in a dysoxic rather than an anoxic environment, according to the seasonal model of Tyson & Pearson (1991), which best fits the great epicontinental Palaeozoic sea (Legrand 1999). The occurrence of bivalves (listed above) does not necessarily contradict this. Rather than to see in them a benthic fauna, they may have belonged to the epiplankton attached to algae as pseudoplankton (Seilacher *et al.* 1968), as has been suggested for small brachiopods (Ruedemann 1934, Havlíček 1967, Spjeldnaes 1967).

The graptolites are of small size, limited to two taxa, and are confined to a single sandy calcareous bed. They indicate an unfavourable local environment with restricted communications.

Above the basal claystones, all claystones are light grey in colour, as also observed in the Přídolí strata of the Ougarta Mountains. The siltstones become siltier and more numerous higher in the section. The environment is interpreted to have remained dysoxic, although richer in oxygen, if the Strophochonetidae-Homalonotinae association, so common in the Algerian Sahara, is regarded as benthic and indicative of shallow water.

Better oxygenation and increasing detrital input are evident at the base of the Touat Sandstone Formation. The accumulation of bivalves from different environments and with different life habits (endobenthic, semi-endobenthic, epibenthic), together with borings into the largest shells indicate reworking within a thanatocoenosis. The taxonomic diversity and the large size of some shells suggest both a better oxygenated environment and a more abundant food supply. The origin of the sediment remains uncertain; the most probable source is from the south because clastic sedimentation had begun in the Western Tassilis at the end of the Wenlock, although the borders with the Eglabs cannot be ignored as another potential source.

A decrease in water depth stratigraphically upwards is also suggested by the increase in abundance of trace fossils. However, the environment remained marine and the shelly beds show complete faunal changeovers at several stratigraphical levels.

Comparison with the surrounding regions

To the northwest. – The Ougarta Mountains. The upper Silurian of Touat appears to differ from that of the Ougarta Mountains, although it is contiguous with it. In the Draa Oued Ali section, the Přídolí extends through most of the middle member of the Oued Ali Clays Formation (except for the calcareous beds and the basal claystones of Ludlow age) and the lower part of the upper member (Legrand 1985). It consists of light grey claystones, approximately 250 m thick, with rare carbonate beds, but without notable silty interbeds, in which graptolites, although present, are rare, bivalves are common, and several levels of scyphonocrinids occur.

Gourara. In the Djebel Hèche section, the Přídolí is represented by much of the *ca* 250 m thick upper member of the Fegaguira Clay (Legrand 1985). It is mainly argillaceous, but graptolites are absent and bivalves rare.

In conclusion, the upper Silurian of Touat seems to be more condensed, but siltier than the time equivalent deposits to the north. It lacks graptolites and scyphocrinids, but it is rich in brachiopods and large bivalves. Structural elements such as the Sba Basin lie between these two regions, and may have played a rôle prior to the deposition of Přídolí.

To the southeast. – Azzel Matti. The upper Silurian of this region has not been studied extensively from a biostratigraphical viewpoint. In the more northerly section, known as the Aïn ech Cheik section, the Přídolí is represented mainly by the upper member of the Aïn ech Cheikr Clay Formation (except for the carbonate sequence at the base of the Ludlow), about 240 m thick. The Silurian-Devonian boundary may be located in the upper part of this argillaceous formation or in the lower part of the overlying Sebkha Mekerrhane Sandstone Formation (= Aïn ech Cheikr Sandstone Formation, a name previously used for an Ordovician formation; Legrand 1985). It is a thick, argillaceous unit with numerous, intercalated silty and sandy layers, somewhat similar to the Touat Formation, but essentially barren of fossils.

Systematic palaeontology

All graptolites come from a calcareous, sandy bed (see Fig. 3), in which they are usually preserved as more or less flattened internal moulds. Traces of periderm are rare. The most delicate parts, such as the apertural spines, are locally preserved, but it is difficult to assess the extent of preservation of the apertural lappets.

The specimens described herein are stored at University Lyon 1, Laboratoire Paléoenvironnement et Paléobiosphère, Pôle Collections.

Order Graptoloidea Lapworth, 1875
Suborder Monograptina Lapworth, 1880
Family Monograptidae Lapworth, 1873

Genus *Pristiograptus* Jaekel, 1889

***Pristiograptus* cf. *tumescens minor* (Wood, 1900)**
Figure 4A–D

cf. 1855 *Graptolites ludensis* var. *minor* (McCoy); M'Coy, p. 5 (*nomen nudum*).
cf. 1900 *Monograptus tumescens* var. *minor* (M'Coy). – Wood, p. 459, pl. 25, figs 6A, B.
cf. 1910 *Monograptus tumescens* var. *minor* (McCoy). – Elles & Wood, p. 381, text-fig. 250, pl. 37, figs 13a–c.
cf. 1943 *Monograptus tumescens* var. *minor* (McCoy). – Přibyl, p. 18, text-fig. 1, figs ?4, ?5; text-fig. 2, fig. CH.
cf. 1948 *Pristiograptus* (*Pristiograptus*) *tumescens minor* (McCoy). – Přibyl, p. 77.
cf. 1952 *Pristiograptus* (*Pristiograptus*) *tumescens* cf. *minor* (M'Coy). – Münch, p. 87, pl. 18, fig. 13.
cf. 1967 *Pristiograptus tumescens minor* (Wood). – Ulst *in* Gailite *et al.*, p. 249, fig. 64, pl. 28, figs 12, 13.
cf. 1997 *Pristiograptus tumescens minor* (M'Coy). – Strachan, p. 114.

Material. – A dozen internal moulds in semi-relief: 1251 to a1–12, b1. Upper Member of the Fenourine Clays Formation, Tamest section (Touat region); association σ3β3; biozone uncertain, lower Ludlow.

Description. – Rhabdosomes usually of small size, from about 10 mm to as much as 12 or 15 mm long. The dorsal margin is often ventrally curved from the proximal end up to the level of th5 or th6, even of th7. The angle of divergence from the axis of rhabdosome is about 10°. The sicula follows this curvature. Further dorsal wall is straight or, more rarely, gently curved, with the sicula forming a slight hump. The rhabdosome widens gradually from 0.8–0.9 mm across the aperture of th1 (0.7–1 mm) to 1.5–1.6 mm at the level of th4 (sometimes a little less: 1.3–1.4 mm) and reaches a maximum of 1.6–1.8 mm (exceptionally 2.2 mm) distally. The sicula is 1.8–2.1 mm long, its apex often attaining a level between the apertures of th3 and th4. The sicular aperture is 0.2–0.4 mm wide and lacks an apertural tongue, but possesses a tiny virgella. Th1, the ventral prothecal wall of which is more or less concave, is 1.0–1.2 mm long; its aperture is clearly everted and its border has been thickened in one specimen (Fig. 3D). The remainder of the thecae are tubes normally 2 mm long (1.8–2.2 mm) and 0.4 mm wide, with a thecal overlap ranging from 2/3 to 3/5. Thecae are inclined 30–35° to the axis of the rhabdosome. Their apertures seem to be moderately everted, but the apertural border in flattened rhabdosomes appears to be thick and very slightly wavy. There are 13–14 thecae in 10 mm.

Discussion. – The specimens resemble *Colonograptus colonus colonus* (Barrande) because of their appearance and the proximal ventral curvature. The size is smaller than usual for this species in which the width attains a maximum of 2.0–2.3 mm. The number of thecae in 10 mm is also similar. On the other hand, the sicula is longer (2 mm instead of 1.6 mm) and the initial thecae seem to be tubular with a simple aperture. However, in some specimens th1 shows a concavo-convex ventral wall, which in flattened specimens may indicate the outline of apertural lappets, as in *praedeubeli* which is of uncertain generic affiliation. However, this is not what one observes in *Colonograptus colonus colonus*, including the original material (Přibyl 1942, Urbanek 1958) and in figures that differ from it (see Jaeger 1978, figs 6–8). One might suppose that the apertural lappets have been mechanically destroyed, but, as the destruction would have to have affected all specimens, this seems unlikely.

These specimens also resemble the type specimens of *Pristiograptus tumescens minor* (Wood) in both their general form and the ventral curvature of the proximal part. However, the identity of *P. t. minor* is problematical.

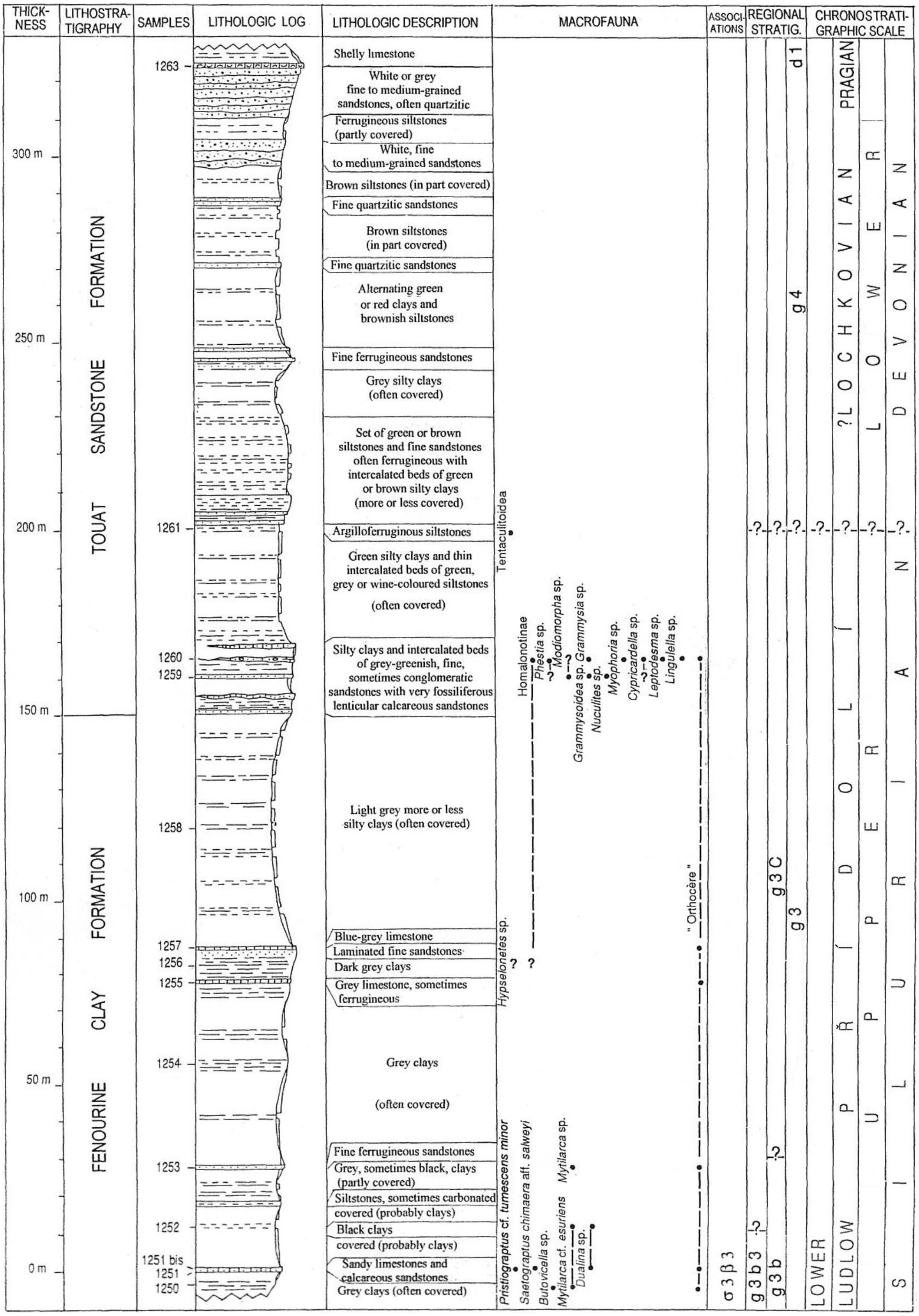


Figure 3. Lithological and stratigraphical logs of the Tamest section (upper Silurian– lowermost Devonian; Legrand, January 1968, unpublished).

The subspecies *Graptolites ludensis minor was* described by McCoy (1855), but not figured. Wood (1900), believing that she had found McCoy's originals, attributed the subspecies to McCoy, but related it to the species *tumescens* with which it is associated. Two specimens were figured (Wood 1900, pl. 25, figs 6A, B). Elles & Wood (1910, pl. 37, figs 13a–c) adopted Wood's viewpoint and figured three specimens and the proximal end of one of them (text-fig. 250), but did not define the morphology of the taxon besides a maximum length of 13 mm. Přibyl (1942), wrongly in my opinion, attributed the taxon to McCoy and chose as lectotype the specimen figured by Wood (1922, pl. 25, fig. 6A). Strachan (1997) adopted the same view and identified the lectotype as specimen BU 1475 (housed in the Lapworth Museum, University of Birmingham). For Elles & Wood (1911) the subspecies *minor* differs from species *tumescens* only in its smaller size. However, this subspecies has never been fully described, although the lectotype of *tumescens* has been refigured with additional information by Zalasiewicz (*in* Zalasiewicz *et al.* 2000). According to Elles & Wood, the maximum breadth is 2.0 mm and "the thecae show a somewhat thickened apertural margin, which after compression gives rise to a distinct denticle". The number of thecae in 10 mm is typically 9–10, but is 12–13 in the more robust forms. The sicula would be less than 2 mm long.

In conclusion, although the status of *P. tumescens minor* remains insecure, the identity with the Touat specimens is considered most likely on present evidence.

Stratigraphical range. – In the British Isles *Pristiograptus tumescens minor* is associated with the biozonal index species *Pristiograptus tumescens*, collected from near the top of the lower Ludlow (Gorstian) by Rickards (1989). In Bohemia, this species characterizes the transition between the *scanicus* Biozone and the *fritschi linearis* Biozone. This is the first time that this species has been recorded from the Algerian Sahara. If it has the same range, it could belong to the association σ3β3 characterizing substage g3b3 (the upper part of the lower Ludlow), but this remains to be confirmed. It should be noted that by bringing these specimens closer to *Colonograptus*, an older age (substage g3b2) (the middle part of the lower Ludlow) would be suggested.

***Saetograptus chimaera* aff. *salweyi* (Lapworth, 1880)**
Figure 4E, F

aff. 1873 *Monograptus salweyi* sp. nov.; J. Hopkinson, p. 520 (*nomen nudum*).
aff. 1880 *Monograptus Salweyi* Hopk. – Lapworth, pp. 150, 151, pl. 4, figs 2a, 2b.
aff. 1884 *Monograptus chimaera* (Barrande). – La Touche, p. 77, tab. 18, fig. 571.
aff. 1900 *Monograptus chimaera* var. *salweyi* Wood. – Wood, p. 472, text-fig. 18, pl. 18, figs 19A, B.
aff. 1910 *Monograptus chimaera* Barr. var. *Salweyi* (Hopkinson MS). – Elles & Wood, p. 400, text-fig. 267a, b, pl. 34, fig. 5a–d.
aff. 1935 *Monograptus chimaera* Barr. var. *Salweyi* (Hopk.). – Ianishevsky, pp. 25, 26, pl. 3, figs 8, 9a, b.
aff. 1938 *Monograptus* cf. *uncinatus* var. *orbatus* Wood. – Münch, pp. 60, 61, pl. 5.
aff. 1942 *Pristiograptus* (*Saetograptus*) *chimaera Salweyi* (Lapworth, 1880, Hopkinson MS). – Přibyl, pp. 14–16, text-fig. 3, figs 1, 2.
aff. 1945 *Monograptus chimaera* var. *Salweyi* Hopk. – Waterlot, p. 74, tab. 29, fig. 308.
aff. 1948 *Pristiograptus* (*Saetograptus*) *Salweyi* (Lapworth). – Přibyl, p. 81.
aff. 1952 *Saetograptus chimaera salweyi* Lpw.-Hopk. MS. – Münch, p. 97, pl. 24, fig. 3a, b.
aff. 1956 *Pristiograptus* (*Saetograptus*) *chimaera salweyi* (Lapworth). – Tomczyk, pp. 56, 57, 91, 92, 117, figs 16c, d, tab. 8, fig. 1.
aff. ?1958 *Saetograptus chimaera salweyi* (Hopkinson). – Urbanek, pp. 56, 57, pl. 2, fig. 3a, b.
aff. ?1958 *Saetograptus chimaera* var. *salweyi* (Lapworth). – Spasov, p. 63, pl. 9, fig. 6.
aff. 1965 *Saetograptus chimaera salweyi* (Lapworth). – Obut & Sobolevskaya, p. 74, pl. 13, fig. 6.
aff. 1997 *Saetograptus* (*Saetograptus*) *chimaera salweyi* (Lapworth). – Strachan, p. 118.

Material. – Seven flattened specimens: 1251 bis d1–7. Upper Member of the Fenourine Clays Formation, Tamest section (Touat region); association σ3β3; biozone uncertain, lower Ludlow.

Description. – Rhabdosome small, barely exceeding 10 mm long. The dorsal wall of the rhabdosome is straight, with a slight, concavo-convex curvature at the level of the sicula. The width of the rhabdosome is 0.7 mm across the aperture of th1 (spine not included). At first it widens slowly: 0.8 mm at th2, 1 mm at th4, to 1.6 mm distally. However, in one specimen, the breadth remains 1 mm throughout the length of the rhabdosome. The sicula is at least 1.6 mm long, with the apex between the level of the apertures of th3 and th4, although this is difficult to define accurately. It is 0.2 mm wide aperturally. The virgella is short (0.2 mm long). Thecae are simple tubes with th1 showing a slightly concave ventral wall. Th1 is 1 mm long and mature thecae are between 1.6 and 1.8 mm long and 0.4 mm wide; the amount of overlap is ¾ and the angle of inclination 35°. At the level of their apertures, the thecae possess two lateral spines, 0.3–0.4 mm long, rising from each side of the lateral border of the aperture; they curve more or less towards the sicula. There are 8 thecae in the first 5 mm and 14–15 in the following 10 mm of the rhabdosome.

Discussion. – These specimens clearly belong to the *Saetograptus chimaera* group with which they share the thecal style and the characteristic lateral thecal spines. However, they do not seem to fit any known taxon. They are similar to *S. chimaera salweyi* (Lapworth) in their small size, nearly straight aspect and slight width. They differ from it by the shorter spines and high number of thecae in 10 mm. This is possibly a local subspecies that cannot be assigned to any known taxon because of the poor quality of the material available. In some characters such as the number of thecae in 10 mm, the specimens are similar to *Saetograptus*? *leintwardinensis* (Hopkinson). However, the form of the sicula and the position of the spines rule out such link. Indeed, Wood (1900) categorically, and Elles & Wood (1911) more cautiously describe the origin of the spines in *S.*? *leintwardinensis* as dorsal and not lateral, an opinion shared by R.B. Rickards (written communication, February–March 2004), although Maletz (1997) has disputed this distinction.

Stratigraphical range. – The available data on the range of *S. chimaera salweyi* are divergent. According to Rickards (1976), the subspecies occurs in the upper part of the *nilssoni* Biozone and the *scanicus* Biozone of the British Isles. However, Lawson & White (1989) recorded *S. chimaera salweyi* only in the *tumescens* Biozone. In Bohemia, Přibyl (1942, 1948) reported this subspecies from the *nilssoni* Biozone and the *scanicus* Biozone, whereas in Poland Teller (1969) attributed to it a shorter range in the boundary interval of the *invertus* and *hemiaversus* subbiozones, equivalent to the upper part of the *tumescens* Biozone. As the Saharan specimens are presently known only from one locality in association with another taxon of uncertain age and belonging to the association σ3β and more probably σ3β3, an early Ludlow age only can be inferred.

The Silurian fauna of Touat in the north Gondwanan context

The Ludlow graptolites of the Touat region show a noteworthy local specificity as they are pelagic species, whereas the occurrence of numerous species from Bohemia in the Algerian Sahara (Legrand 1981) in silled basins poses a problem of circulation. On the other hand, the other Silurian faunas of the Touat area, such as the bivalves, are typically Gondwanan with obvious affinities with the faunas of Bohemia, the Montagne Noire and Sardinia. This also applies to the bivalves from the western Algerian Sahara.

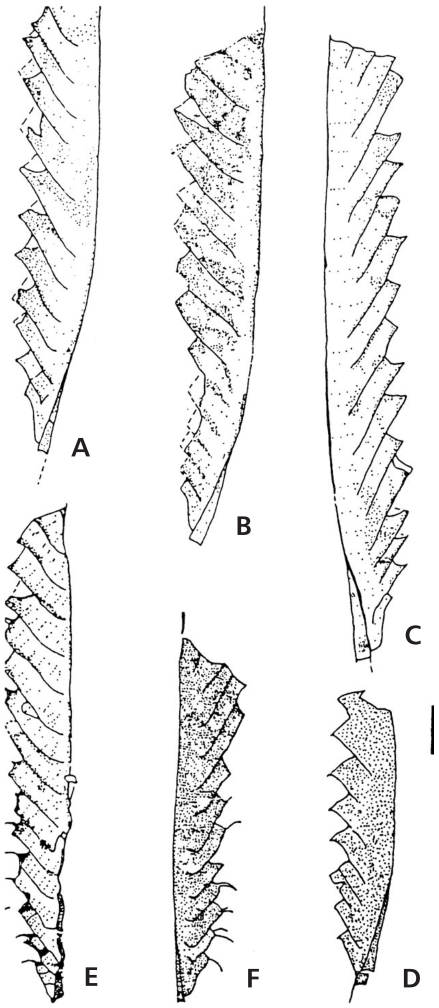


Figure 4. Graptolites of the Tamest section. • A–D – *Pristiograptus* cf. *tumescens minor* (Wood). • A – specimen 1251bis a1; B – specimen 1251bis a6; C – specimen 1251bis a7; D – specimen 1251bis a8. • E, F – *Saetograptus chimaera* aff. *salweyi* (Lapworth). E – specimen 1251 bis d1; F – specimen 1251bis d2. Scale bar represents 1 mm for all specimens.

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