

## The type Ludlow Series: Biostratigraphy - chitinozoa

A chitinozoan zonation for the Ludlow rocks of the U.K. has only been established for the type area. Dorning (1981b) published a summary of chitinozoan distributions in the type Ludlow Series, but a more detailed and comprehensive account by Sutherland (1994) established twelve informally numbered biozones which are related directly to lithostratigraphy. The global standard chitinozoan zonation for the Ludlow Series published by Verniers *et al.* (1995) contains only three biozones, namely the zones of *Angochitina elongata*, *Eisenackitina philipi* and *Eisenackitina barrandei*, with incomplete coverage of the series. This suggests that Sutherland's (1994) zonation may be of only local value, or that more work is needed to test its applicability to other Ludlow successions.

Sutherland (1994, p. 70) summarized the main developments in chitinozoan faunas through the Ludlow Series, as follows.

- **Upper Wenlock and lower Gorstian (Lower Elton Formation).** Characterized by the presence of *Conochitina*, particularly *C. rudda* Sutherland and *C. pachycephala* Eisenack.
- **Lower Gorstian (Middle Elton Formation).** *Conochitina* persists but is less dominant. *Cingulochitina* is common.
- **Upper Gorstian (Upper Elton, Lower Bringewood and Upper Bringewood formations).** Characterized by the presence of *Belonechitina* and *Eisenackitina toddingensis* Sutherland.
- **Lower Ludfordian (Lower Leintwardine and Upper Leintwardine formations).** Increased importance of *Eisenackitina lagenomorpha* (Eisenack). Appearance of *Calpichitina* (*Calpichitina*) sp. aff. *hemsensis* (Laufeld).
- **Upper Ludfordian (Lower Whitcliffe and Upper Whitcliffe formations).** Characterized by the high abundance and frequency of *Eisenackitina philipi* Laufeld. *Eisenackitina barrandei* Paris & Kriz occurs at the top of the Upper Whitcliffe Formation.

See 'Distribution of chitinozoa in the Ludlow Series' for ranges of taxa, based on Sutherland's (1994) data from the type Ludlow Series, and Verniers *et al.*'s (1995) appraisal of global ranges.

Dorning, K.J. 1981b. Silurian chitinozoa from the type Wenlock and Ludlow of Shropshire. *Review of Palaeobotany and Palynology*, **34**, 205-208.

Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).

Verniers, J., Nestor, V., Paris, F., Dufka, P., Sutherland, S. & Van Grootel, G. 1995. A global Chitinozoa biozonation for the Silurian. *Geological Magazine*, **132**, 651-666.

(continued...)

## **The type Ludlow Series: Biostratigraphy - chitinozoa (continued)**

See: [Angochitina elongata](#) Biozone, [Chitinozoan Biozone 1](#), [Chitinozoan Biozone 2](#), [Chitinozoan Biozone 3](#), [Chitinozoan Biozone 4](#), [Chitinozoan Biozone 5](#), [Chitinozoan Biozone 6](#), [Chitinozoan Biozone 7](#), [Chitinozoan Biozone 8](#), [Chitinozoan Biozone 9](#), [Chitinozoan Biozone 10](#), [Chitinozoan Biozone 11](#), [Chitinozoan Biozone 12](#), [Eisenackitina barrandei](#) Biozone, [Eisenackitina philipi](#) Biozone.

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## ***Angochitina elongata* Biozone**

### **Microfauna**

The base of the *Angochitina elongata* Biozone (of Verniers *et al.* 1995) is defined by the first occurrence of *Angochitina elongata* Eisenack.

*Angochitina echinata* Eisenack, *Belonechitina lauensis* (Laufeld) and *Eisenackitina intermedia* (Eisenack) appear at about the base of the zone, or slightly higher. *Ancyrochitina desmea* Eisenack, *Belonechitina latifrons* (Eisenack), *Cingulochitina convexa* (Laufeld) and *Conochitina pachycephala* Eisenack all appear below the zone but range into it; *C. pachycephala* disappears just above the base of the zone, *A. desmea* disappears about the middle of the zone, and *B. latifrons* and *C. convexa* both range into the base of the overlying *Eisenackitina philipi* Biozone. *Eisenackitina lagenomorpha* (Eisenack) appears in the upper part of the zone.

See ‘[Distribution of chitinozoa in the Ludlow Series](#)’ for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### **Occurrence**

The base of the *Angochitina elongata* Biozone was defined at the same level, in the same section, and using the same criterion as the base of Sutherland’s (1994) Biozone 4, that is at the appearance of *A. elongata* in the Middle Elton Formation of the Goggin Road section. However, the *A. elongata* Biozone extends upwards to the base of Sutherland’s Biozone 12. It therefore covers a substantial part of the type Ludlow succession, from about the middle of the Middle Elton Formation to just below the top of the Upper Leintwardine Formation.

Sutherland’s (1994) biozones 1-3, underlying the *A. elongata* Biozone, do not correlate with any of Verniers *et al.*’s (1995) zones. The latter authors noted the existence of a stratigraphical interval between their *Sphaerochitina lycoperdoides* Biozone (upper Wenlock) and the *A. elongata* Biozone for which no global chitinozoan biozone had been defined.

In Britain, the *A. elongata* Biozone has only been identified in the type area of the Ludlow Series. Of the species listed by Verniers *et al.* (1995), all have been recorded from the Ludlow Series of the Welsh Borderland by Aldridge *et al.* (1979), Dorning (1981b) or Sutherland (1994), but there are discrepancies in the ranges. For example, *Cingulochitina convexa* was found by Sutherland to be restricted to the Middle Elton Formation in the type Ludlow succession, but was considered by Verniers *et al.* (1995) to range through most of the Ludlow Series, extending below and above the *A. elongata* Biozone. Such discrepancies may arise from differing ranges in different areas, from different ranges being recorded by different authors in the same area, and perhaps even from differing taxonomic concepts between workers.

(continued...)

## ***Angochitina elongata* Biozone (continued)**

- Aldridge, R.J., Dorning, K.J., Hill, P.J., Richardson, J.B. & Siveter, D.J. 1979. Microfossil distribution in the Silurian of Britain and Ireland. *In* Harris, A.L., Holland, C.H. & Leake, B.E. (eds) *The Caledonides of the British Isles - reviewed*. Geological Society of London, Special Publication No. **8**, 433-438.
- Dorning, K.J. 1981b. Silurian chitinozoa from the type Wenlock and Ludlow of Shropshire. *Review of Palaeobotany and Palynology*, **34**, 205-208.
- Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).
- Verniers, J., Nestor, V., Paris, F., Dufka, P., Sutherland, S. & Van Grootel, G. 1995. A global Chitinozoa biozonation for the Silurian. *Geological Magazine*, **132**, 651-666.

See: [Chitinozoan Biozone 4, Distribution of chitinozoa in the Ludlow Series, Goggin Road, Holostratigraphical chart.](#)

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## ***Eisenackitina philipi* Biozone**

### **Microfauna**

The base of the *Eisenackitina philipi* Biozone (of Verniers *et al.* 1995) is defined by the first occurrence of *Eisenackitina philipi* Laufeld.

Verniers *et al.* (1995) listed *Angochitina echinata* Eisenack, *Eisenackitina granosa* (Laufeld) and *Eisenackitina lagenomorpha* (Eisenack) as being present. Their range chart (Verniers *et al.* 1995, fig. 3) shows *A. echinata*, *Eisenackitina intermedia* (Eisenack) and *E. lagenomorpha* ranging through the zone into overlying strata. *E. granosa* and *E. philipi* both appear at the base of the zone; *E. philipi* is restricted to the zone whereas *E. granosa* ranges into the overlying *Eisenackitina barrandei* Biozone. *Belonechitina latifrons* (Eisenack) and *B. lauensis* (Laufeld) disappear just above the base of the zone, while *Angochitina elongata* Eisenack and *Cingulochitina convexa* (Laufeld) disappear at or just below its top.

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### **Occurrence**

In Britain, the *Eisenackitina philipi* Biozone has only been identified in the type area of the Ludlow Series. The base of the *E. philipi* Biozone was defined at the same level, in the same section, and using the same criterion as the base of Sutherland’s (1994) Biozone 12, i.e. at the first appearance of *Eisenackitina philipi*, 0.46 m below the base of the Lower Whitcliffe Formation, in the formation’s basal stratotype section on The Whitcliffe at Ludlow. The biozone extends into the base of the Upper Whitcliffe Formation in the Ludlow area, and is equivalent to Biozone 12 of Sutherland (1994).

Of the species listed by Verniers *et al.* (1995), all have been recorded from the Ludlow Series of the Welsh Borderland by Aldridge *et al.* (1979), Dorning (1981b) or Sutherland (1994), but there are discrepancies in the ranges. For example, *Belonechitina latifrons* ranges from the pre-*elongata* Biozone interval in the lower Ludlow into the base of the *philipi* Biozone according to Verniers *et al.* (1995), a range spanning the interval from the Lower or Middle Elton Formation in the type area to the top of the Upper Leintwardine Formation. Ranges of this species recorded by other authors in the Ludlow type area are: upper Wenlock to the middle of the Elton Group (Aldridge *et al.* 1979); middle of the Elton Group to the top of the Bringewood Group (Dorning 1981b); and Upper Elton Formation to Upper Bringewood Formation (Sutherland 1994: Biozone 5 to the base of Biozone 8). *Eisenackitina philipi* itself was considered by Sutherland (1994) to range from the top of the Upper Leintwardine Formation into the base of the Upper Whitcliffe Formation in the Ludlow type area, whereas Dorning (1981b) depicted its range as being restricted to the entire Leintwardine Group with no extension into the Whitcliffe Group. In other words, both the first and last appearance datums of the species according to Sutherland (1994) are later than those of Dorning (1981b). Such discrepancies may arise from differing ranges in different areas, from different ranges being recorded by different authors in the same area, and perhaps even from differing taxonomic concepts between workers.

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## ***Eisenackitina philipi* Biozone (continued)**

- Aldridge, R.J., Dorning, K.J., Hill, P.J., Richardson, J.B. & Siveter, D.J. 1979. Microfossil distribution in the Silurian of Britain and Ireland. *In* Harris, A.L., Holland, C.H. & Leake, B.E. (eds) *The Caledonides of the British Isles - reviewed*. Geological Society of London, Special Publication No. **8**, 433-438.
- Dorning, K.J. 1981b. Silurian chitinozoa from the type Wenlock and Ludlow of Shropshire. *Review of Palaeobotany and Palynology*, **34**, 205-208.
- Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).
- Verniers, J., Nestor, V., Paris, F., Dufka, P., Sutherland, S. & Van Grootel, G. 1995. A global Chitinozoa biozonation for the Silurian. *Geological Magazine*, **132**, 651-666.

See: [Chitinozoan Biozone 12, Distribution of chitinozoa in the Ludlow Series, Holostratigraphical chart, The Whitcliffe.](#)

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## ***Eisenackitina barrandei* Biozone**

### **Microfauna**

The base of the *Eisenackitina barrandei* Biozone (of Verniers *et al.* 1995) is defined by the first occurrence of *Eisenackitina barrandei* Paris & Kríz.

*Eisenackitina barrandei* is restricted to the zone. *Sphaerochitina sphaerocephala* (Eisenack) appears at or just above the base of the zone, and ranges into overlying strata. *Angochitina echinata* Eisenack, *Eisenackitina intermedia* (Eisenack) and *E. lagenomorpha* (Eisenack) range through the zone. *Eisenackitina granosa* (Laufeld) has its last appearance in the lower part of the zone, and *Pterochitina perivelata* (Eisenack) has its first appearance in the upper part (Verniers *et al.* 1995, fig. 3).

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### **Occurrence**

In Britain, the *Eisenackitina barrandei* Biozone is known only from the Ludlow type area. The highest chitinozoan fauna recorded by Sutherland (1994), representing the *E. philipi* Biozone, was collected about 2.4 m above the base of the Upper Whitcliffe Formation in its basal stratotype section on The Whitcliffe. Verniers *et al.* (1995), however, noted that there was evidence for the presence of the *E. barrandei* Biozone in the upper part of the Upper Whitcliffe Formation of the Ludlow area, citing Richardson & Rasul (1990). Consequently, the base of the *E. barrandei* Biozone is placed within the Upper Whitcliffe Formation of the type Ludlow succession. Verniers *et al.* (1995) depicted a short interval separating the *E. philipi* and *E. barrandei* biozones on their figures.

Richardson & Rasul (1990, fig. 10b) figured a specimen of *Eisenackitina barrandei* from the top of the Upper Whitcliffe Formation, between 0.23 and 0.26 m below the top of the Ludlow Series, near Downton, west of Ludlow. Of the other species that appear in the zone (according to Verniers *et al.* 1995), *S. sphaerocephala* was depicted by Aldridge *et al.* (1979) as ranging through the whole of the Whitcliffe Group, and by Dorning (1981b) as ranging through the entire Leintwardine and Whitcliffe groups.

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## ***Eisenackitina barrandei* Biozone (continued)**

- Aldridge, R.J., Dorning, K.J., Hill, P.J., Richardson, J.B. & Siveter, D.J. 1979. Microfossil distribution in the Silurian of Britain and Ireland. *In* Harris, A.L., Holland, C.H. & Leake, B.E. (eds) *The Caledonides of the British Isles - reviewed*. Geological Society of London, Special Publication No. **8**, 433-438.
- Dorning, K.J. 1981b. Silurian chitinozoa from the type Wenlock and Ludlow of Shropshire. *Review of Palaeobotany and Palynology*, **34**, 205-208.
- Richardson, J.B. & Rasul, S.M. 1990. Palynofacies in a Late Silurian regressive sequence in the Welsh Borderland and Wales. *Journal of the Geological Society, London*, **147**, 675-686.
- Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).
- Verniers, J., Nestor, V., Paris, F., Dufka, P., Sutherland, S. & Van Grootel, G. 1995. A global Chitinozoa biozonation for the Silurian. *Geological Magazine*, **132**, 651-666.

See: [Distribution of chitinozoa in the Ludlow Series, Holostratigraphical chart](#).

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## Chitinozoan Biozone 1

### Microfauna

Chitinozoan Biozone 1 of Sutherland (1994) is characterized by:

*Ancyrochitina gogginensis* Sutherland, *Ancyrochitina* cf. *pachyderma* Laufeld, *Bursachitina* sp. A of Sutherland (1994), *Conochitina rudda* Sutherland, *Conochitina* sp. aff. *elegans* Eisenack, *Conochitina* cf. *proboscifera* forma *truncata* Laufeld and *Conochitina pachycephala* Eisenack.

Other taxa present include *Ancyrochitina* sp. A of Sutherland (1994), *Conochitina* sp. A of Sutherland (1994) and *Rhabdochitina conocephala* Eisenack. All these taxa appear in the Wenlock and cross the Wenlock-Ludlow boundary at Pitch Coppice Quarry (Sutherland 1994, text-fig. 37), the boundary stratotype for the base of the Ludlow Series.

*A. cf. pachyderma* has its last appearance in the Lower Elton Formation, 0.1 m above the base of the Ludlow Series at Pitch Coppice Quarry (sample PC2). The last appearance of *C. sp. aff. elegans* is at locality A1 of the Goggin Road section (sample GR9). Its disappearance marks the top of Biozone 1. *Ancyrochitina* sp. B of Sutherland (1994) has its first appearance in sample GR9, and therefore at the top of Biozone 1 (Sutherland 1994).

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### Occurrence

Chitinozoan Biozone 1 has its base in the Much Wenlock Limestone Formation, and encompasses the lowest 14.8 m of the Lower Elton Formation in the type Ludlow area (according to Sutherland’s (1994) interpretation of the section exposed along the Goggin Road).

Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).

See: [Distribution of chitinozoa in the Ludlow Series, Goggin Road, Holostratigraphical chart, Pitch Coppice Quarry.](#)

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## Chitinozoan Biozone 2

### Microfauna

The base of Chitinozoan Biozone 2 of Sutherland (1994) is placed above the disappearance of *Conochitina* sp. aff. *elegans* Eisenack in sample GR9 (Goggin Road section). The biozone contains very few characteristic taxa, except for *Conochitina* sp. A of Sutherland (1994) in its lower part, and is perhaps better regarded as an interzonal interval between biozones 1 and 3.

*Conochitina* sp. A has its last appearance in sample GR14 of Sutherland (1994), from locality A6 of White & Lawson (1978) in the Lower Elton Formation of the Goggin Road section.

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### Occurrence

The base of Chitinozoan Biozone 2 is at about the base of locality A1 of White & Lawson (1978), in the Goggin Road section of the type Ludlow area. It was estimated by Sutherland (1994) to be 14.8 m above the base of the Ludlow Series (and the base of the Lower Elton Formation). The biozone extends upwards to the base of Chitinozoan Biozone 3, in the lower part of the Middle Elton Formation of the Goggin Road section.

Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).

White, D.E. & Lawson, J.D. 1978. The stratigraphy of new sections in the Ludlow Series of the type area, Ludlow, Salop, England. *Report of the Institute of Geological Sciences*, No. **78/30**, 1-10.

See: [Chitinozoan Biozone 3, Distribution of chitinozoa in the Ludlow Series, Goggin Road, Holostratigraphical chart.](#)

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## Chitinozoan Biozone 3

### Microfauna

The base of Chitinozoan Biozone 3 (Sutherland 1994) is defined by the appearance of *Cingulochitina gorstyensis* Sutherland in sample GR19 from the Middle Elton Formation, probably at locality A10, in the Goggin Road section. Assemblages from the biozone also contain *Bursachitina* sp. B of Sutherland (1994), *Cingulochitina convexa* Laufeld and *Cingulochitina* sp. A of Sutherland (1994). *Cingulochitina convexa* has its first appearance in sample GR21 (Middle Elton Formation, locality A11?, Goggin Road section), while *Bursachitina* sp. B and *Cingulochitina* sp. A both appear in sample GR23 (Middle Elton Formation, localities A12-A14, Goggin Road section). All these taxa range into overlying zones. *Bursachitina* sp. B is generally restricted to the Middle Elton Formation (Biozone 3 and the base of Biozone 4), although there is one possible record from the Lower Bringewood Formation.

*Ancyrochitina gogginensis* Sutherland, *Conochitina rudda* Sutherland and *C. cf. proboscifera* forma *truncata* Laufeld, recorded from Chitinozoan Biozone 1, reappear in Biozone 3, although *A. gogginensis* and *C. rudda* have sporadic occurrences there. All three taxa range above Biozone 3.

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### Occurrence

Comparison of locality information (White & Lawson 1978, fig. 2; Sutherland 1994, text-fig. 6) shows the base of Chitinozoan Biozone 3 (sample GR 19) to be at localities A10-A11 of White & Lawson, in the Goggin Road section of the type Ludlow area. Sutherland’s text-fig. 39 implies that it is at the base of the strata exposed at these localities, i.e. at the base of A10. White & Lawson (1978) placed the base of A10 about 23 m above the base of the Middle Elton Formation, however, whereas Sutherland (1994, p. 92) placed the base of Chitinozoan Biozone 3 about 27 m above the base of the formation.

The top of the biozone coincides with the base of Chitinozoan Biozone 4, also in the Middle Elton Formation of the Goggin Road section.

Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).

White, D.E. & Lawson, J.D. 1978. The stratigraphy of new sections in the Ludlow Series of the type area, Ludlow, Salop, England. *Report of the Institute of Geological Sciences*, No. **78/30**, 1-10.

See: [Chitinozoan Biozone 4, Distribution of chitinozoa in the Ludlow Series, Goggin Road, Holostratigraphical chart.](#)

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## Chitinozoan Biozone 4

### Microfauna

The base of Chitinozoan Biozone 4 (Sutherland 1994) is defined by the appearance of *Angochitina elongata* Eisenack, in sample GR30 (Middle Elton Formation, localities A16-A18, Goggin Road section). The appearance of *A. elongata* in the Goggin Road section also defines the base of the *A. elongata* Biozone (Verniers *et al.* 1995).

*Angochitina* sp. aff. *echinata* Eisenack, *Belonechitina lauensis* Laufeld and *Eisenackitina intermedia* (Eisenack) appear at the same level as *A. elongata* in the Goggin Road section. *Eisenackitina toddingensis* Sutherland, which appears about 2 m above the base of the zone (sample GR31), is common throughout most of Chitinozoan Biozone 4. *Cingulochitina* sp. A of Sutherland (1994) has its last appearance 2 m above the base of the zone (sample GR31) and *Cingulochitina convexa* (Laufeld) disappears 6 m above the base of the zone (sample GR33, localities A19-A20). *Conochitina rudda* Sutherland disappears 4.8 m below the top of the zone, in the Upper Elton Formation (sample GR42).

Also present in microfaunas from the zone are *Bursachitina* sp. B of Sutherland (1994), *Cingulochitina gorsteyensis* Sutherland, and *Conochitina pachycephala* Eisenack, all of which have sporadic occurrences, and all of which range into higher zones.

See '[Distribution of chitinozoa in the Ludlow Series](#)' for ranges of taxa, based on Sutherland's (1994) data from the type Ludlow Series, and Verniers *et al.*'s (1995) appraisal of global ranges.

### Occurrence

The base of Chitinozoan Biozone 4 lies within the Middle Elton Formation, at localities A16-A18 of White & Lawson (1978) in the Goggin Road section of the type Ludlow area. Its exact level within the 4.3 m of strata exposed at these localities has not been determined. White & Lawson (1978, fig. 3) placed strata at localities A16-A18 about 57 to 61 m above the base of the Middle Elton Formation, whereas Sutherland (1994, p. 92) placed the base of the zone 71m above the base of the formation.

The top of Chitinozoan Biozone 4 coincides with the base of Chitinozoan Biozone 5 in the Upper Elton Formation of the same section.

(continued...)

## **Chitinozoan Biozone 4 (continued)**

- Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).
- Verniers, J., Nestor, V., Paris, F., Dufka, P., Sutherland, S. & Van Grootel, G. 1995. A global Chitinozoa biozonation for the Silurian. *Geological Magazine*, **132**, 651-666.
- White, D.E. & Lawson, J.D. 1978. The stratigraphy of new sections in the Ludlow Series of the type area, Ludlow, Salop, England. *Report of the Institute of Geological Sciences*, No. **78/30**, 1-10.

See: [Angochitina elongata Biozone](#), [Chitinozoan Biozone 5](#), [Distribution of chitinozoa in the Ludlow Series](#), [Goggin Road](#), [Holostratigraphical chart](#).

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## Chitinozoan Biozone 5

### Microfauna

The base of Chitinozoan Biozone 5 in the type Ludlow area is defined by the first local appearances of *Ancyrochitina ancyrea* (Eisenack) and *A. cf. primitiva* Eisenack in sample GR45, estimated by Sutherland (1994) to be about 16 m above the base of the Upper Elton Formation in the Goggin Road section. Both range into higher zones.

*Belonechitina latifrons* (Eisenack) and *Ancyrochitina aymestreyensis* Sutherland both appear in sample GR48 from the Upper Elton Formation, estimated by Sutherland (1994) to be about 6 m above the base of Biozone 5, and both occur sporadically throughout the upper part of the zone, ranging into higher zones.

*Conochitina cf. proboscifera* forma *truncata* Laufeld has its last appearance in sample GR48. The highest occurrence of *Bursachitina* sp. B (of Sutherland 1994) may be about 4 m below the top of the zone, where it is represented by a possible specimen from sample GR59, 4 m above the base of the Lower Bringewood Formation in the Goggin Road section. The last appearance of *Cingulochitina gorsteyensis* Sutherland appears to be about the top of the zone (Sutherland 1994, text-fig. 36).

Other taxa recorded from Biozone 5 include *Ancyrochitina gogginensis* Sutherland, *Ancyrochitina* sp. B of Sutherland (1994), *Angochitina elongata* Eisenack, *Belonechitina lauensis* (Laufeld), *Conochitina pachycephala* Eisenack, *Eisenackitina intermedia* (Eisenack) and *Eisenackitina toddingensis* Sutherland. All appear below Biozone 5, and range through it into higher strata (Sutherland 1994, text-fig. 36).

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### Occurrence

Sutherland (1994, p. 92) placed the base of the biozone 18.8 m below the top of the Upper Elton Formation in the Goggin Road section of the Ludlow type area (i.e. about 16 m above the base of the formation, given Sutherland’s estimate of thickness of 35 m). Sutherland’s estimate of the formation’s thickness is much greater than White & Lawson’s (1978), however, who considered the Upper Elton Formation to be only 19 m thick in the Goggin Road section. In consequence, there is some uncertainty over the exact position of the base of Biozone 5 in the Goggin Road section, although Sutherland (1994, text-fig. 40) showed it to be about the middle of the formation.

The top of the biozone coincides with the base of Chitinozoan Biozone 6 in the Lower Bringewood Formation of the Goggin Road section.

(continued...)

## **Chitinozoan Biozone 5 (continued)**

- Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).
- White, D.E. & Lawson, J.D. 1978. The stratigraphy of new sections in the Ludlow Series of the type area, Ludlow, Salop, England. *Report of the Institute of Geological Sciences*, No. **78/30**, 1-10.

See: [Chitinozoan Biozone 6, Distribution of chitinozoa in the Ludlow Series, Goggin Road, Holostratigraphical chart.](#)

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## Chitinozoan Biozone 6

### Microfauna

The base of Chitinozoan Biozone 6 (Sutherland 1994) is placed at the first occurrence of *Gotlandochitina swifti* Sutherland, in sample GR62, from the Lower Bringewood Formation of the Goggin Road section. *G. swifti* ranges into higher zones.

*Eisenackitina lagenomorpha* (Eisenack) appears close to the base of the zone, but only becomes important in the Ludfordian. *Belonechitina mortimerensis* Sutherland appears 2-3 m below the top of the zone in the Lower Bringewood Formation of the Deer Park Road section (in sample DPR3 according to Sutherland 1994, p. 44, but in sample DPR4 on his text-fig. 41).

*Conochitina pachycephala* Eisenack has its last occurrence in sample GR68, 20 m above the base of the Lower Bringewood Formation (i.e. 12 m above the base of the zone) in the Goggin Road section. *Ancyrochitina* sp. B of Sutherland (1994) has its highest occurrence in sample DPR3 from the Lower Bringewood Formation, about 2 m below the top of the zone in the Deer Park Road section. *Rhabdochitina conocephala* Eisenack has its last appearance near the top of the zone.

Sutherland (1994) reported *Angochitina elongata* Eisenack, *Angochitina* sp. aff. *echinata* Eisenack, *Belonechitina lauensis* Laufeld, *Eisenackitina intermedia* (Eisenack) and *Eisenackitina toddingensis* Sutherland to be common throughout Chitinozoan Biozone 6. Also present in microfaunas from the zone are *Ancyrochitina ancyrea* (Eisenack), *Ancyrochitina aymestreyensis* Sutherland, *Ancyrochitina gogginensis* Sutherland, *Ancyrochitina* sp. A of Sutherland (1994), *Belonechitina latifrons* (Eisenack) and *Bursachitina* sp. A of Sutherland (1994). All range through the zone, appearing in lower zones and continuing to higher levels.

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### Occurrence

The base of Chitinozoan Biozone 6 was estimated by Sutherland (1994, p. 92) to be 8 m above the base of the Lower Bringewood Formation in the Goggin Road section of the type Ludlow area.

The top of the biozone coincides with the base of Biozone 7 in the Lower Bringewood Formation of the Deer Park Road section.

(continued...)



## **Chitinozoan Biozone 6 (continued)**

Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).

See: [Chitinozoan Biozone 7, Deer Park Road, Distribution of chitinozoa in the Ludlow Series, Goggin Road, Holostratigraphical chart.](#)

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## Chitinozoan Biozone 7

### Microfauna

The base of Chitinozoan Biozone 7 (Sutherland 1994) is defined by the appearance of *Gotlandochitina* sp. aff. *villosa* Laufeld in sample DPR2 from the Lower Bringewood Formation of the Deer Park Road section. *G.* sp. aff. *villosa* only occurs in this and the overlying sample, DPR1, about 2 m above the base of the zone.

*Ancyrochitina narcissa* Sutherland has its first appearance in sample DP6, from the Lower Bringewood Formation, about 12 m above the base of the zone in the Deer Park Road section. It ranges into overlying zones.

Other species recorded from Biozone 7, all of which appear below the zone and range into higher zones, include *Ancyrochitina ancyrea* (Eisenack), *Ancyrochitina aymestreyensis* Sutherland, *Ancyrochitina* cf. *primitiva* Eisenack, *Angochitina elongata* Eisenack, *Angochitina* sp. cf. *echinata* Eisenack, *Belonechitina lauensis* (Laufeld), *Belonechitina mortimerensis* Sutherland, *Eisenackitina intermedia* (Eisenack), *Eisenackitina lagenomorpha* (Eisenack) and *Eisenackitina toddingensis* Sutherland. Sutherland (1994) reported *Belonechitina mortimerensis* to be common throughout the zone.

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### Occurrence

Chitinozoan Biozone 7 is based on faunas from the Deer Park Road section in the type Ludlow area, where its base was estimated by Sutherland (1994) to be approximately 25 m below the top of the Lower Bringewood Formation.

The top of the biozone coincides with the base of Chitinozoan Biozone 8 in the Lower Bringewood Formation of the Deer Park Road section.

Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).

See: [Chitinozoan Biozone 8, Deer Park Road, Distribution of chitinozoa in the Ludlow Series, Holostratigraphical chart.](#)

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## Chitinozoan Biozone 8

### Microfauna

The base of Chitinozoan Biozone 8 (Sutherland 1994) is defined by the first occurrence of *Cingulochitina* sp. aff. *cingulata* (Eisenack) in sample DP15 from the Lower Bringewood Formation of the Deer Park Road section. *Vinnalochitina granosa* Sutherland and *Fungochitina* cf. *pistilliformis* (Eisenack) appear at the same level. All range into overlying zones.

*Calpichitina* (*Calpichitina*) sp. aff. *hemsienensis* (Laufeld) has its first appearance in the Upper Bringewood Formation of Sunnyhill Quarry, about 0.4 m below the top of the zone (sample SH17), and *Eisenackitina lagenomorpha*? (Eisenack) appears about 4 m below the top of the zone in the same section (sample SH21).

The highest occurrence of *Belonechitina latifrons* (Eisenack) is 1.45 m above the base of the zone in the Lower Bringewood Formation of the Deer Park Road section (sample DP22). The highest positive occurrence of *Ancyrochitina* cf. *primitiva* Eisenack is 2.1 m above the base of the zone, also in the Lower Bringewood Formation of the Deer Park Road section (sample DP25). *Eisenackitina toddingensis* Sutherland has its last appearance at the same level in the Deer Park Road section, and *Sphaerochitina* cf. *lycoperdoides* Laufeld is restricted to sample DP25. *Belonechitina mortimerensis* Sutherland has its last appearance about 0.13 m below the top of the zone, at the top of the Upper Bringewood Formation in Sunnyhill Quarry (sample SH16). *Ancyrochitina aymestreyensis* Sutherland and *Gotlandochitina swifti* Sutherland disappear respectively 2 m and 8 m below the top of the zone at Aymestrey (Sutherland 1994).

Other taxa recorded from Biozone 8, all of which occur above and below the zone, include *Ancyrochitina ancyrea* (Eisenack), *Ancyrochitina narcissa* Sutherland, *Angochitina elongata* Eisenack, *Belonechitina lauensis* Laufeld, *Bursachitina* sp. A of Sutherland (1994), *Eisenackitina intermedia* (Eisenack) and *Eisenackitina lagenomorpha* (Eisenack).

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### Occurrence

The base of Chitinozoan Biozone 8 is estimated to be approximately 2.5 m below the top of the Lower Bringewood Formation on the Deer Park Road section of the type Ludlow area. Chitinozoan Biozone 8 covers most of the Upper Bringewood Formation. The top of the biozone coincides with the base of Biozone 9, at the top of the Upper Bringewood Formation in Sunnyhill Quarry (Sutherland 1994).

(continued...)

## **Chitinozoan Biozone 8 (continued)**

Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).

See: [Chitinozoan Biozone 9, Deer Park Road, Distribution of chitinozoa in the Ludlow Series, Holostratigraphical chart, Sunnyhill Quarry.](#)

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## Chitinozoan Biozone 9

### Microfauna

The base of Chitinozoan Biozone 9 (Sutherland 1994) is defined by the appearance of *Gotlandochitina*? sp. A (of Sutherland) in sample SH15, immediately below the base of the Lower Leintwardine Formation in Sunnyhill Quarry.

*Ancyrochitina ansarviensis*? Laufeld is represented by a single specimen from sample SH3, approximately 0.1 m above the base of the zone in Sunnyhill Quarry. *Ancyrochitina gogginensis* Sutherland and *A. narcissa* Sutherland both have their last occurrences about 0.2 m above the base of the zone (sample SH4). *Ancyrochitina* sp. A of Sutherland (1994) disappears about 0.6 m above the base of the zone in Sunnyhill Quarry (sample SH8), and *Cingulochitina* sp. aff. *cingulata* (Eisenack) has its last appearance about 0.8 m above the base of the zone (sample SH9). *Vinnalochitina granosa* Sutherland has its last appearance about 3.5 m above the base of the zone in the Sunnyhill Quarry section (sample SH14)

Other taxa recorded, all of which range through the zone, include *Ancyrochitina ancyrea* (Eisenack), *Angochitina elongata* Eisenack, *Angochitina* sp. aff. *echinata* Eisenack, *Belonechitina lauensis* Laufeld, *Eisenackitina intermedia* (Eisenack), and *Eisenackitina lagenomorpha* Eisenack. *E. lagenomorpha* becomes particularly important within Biozone 9 (Sutherland 1994).

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### Occurrence

The base of Chitinozoan Biozone 9 is placed at the top of the Upper Bringewood Formation in Sunnyhill Quarry in the type Ludlow area, immediately below the thin shale at the base of the Lower Leintwardine Formation (Sutherland 1994, text-fig. 47).

The top of the biozone coincides with the base of Chitinozoan Biozone 10, in the Lower Leintwardine Formation of the Sunnyhill section.

Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).

See: [Chitinozoan Biozone 10, Distribution of chitinozoa in the Ludlow Series, Holostratigraphical chart, Sunnyhill Quarry.](#)

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## Chitinozoan Biozone 10

### Microfauna

The base of Biozone 10 (Sutherland 1994) is located at the appearance of *Angochitina milleri* Sutherland in the Lower Leintwardine Formation, in the section above Sunnyhill Quarry (sample SH25). *A. milleri* is restricted to the lower part of Biozone 10, its last occurrence being about 5 m above the base of the zone in the Sunnyhill Quarry section (sample SH31).

*Fungochitina* cf. *pistilliformis* (Eisenack) has its last appearance about 1 m above the base of the zone (sample SH26), *Angochitina elongata* Eisenack and *A. sp. aff. echinata* Eisenack last occur 9.96 m above the base of the zone (sample SH36), and *Eisenackitina lagenomorpha* Eisenack last occurs about 23 m above the base of the zone (sample SH40), all in the Lower Leintwardine Formation of the Sunnyhill Quarry section. *Bursachitina* sp. A of Sutherland (1994) and *Eisenackitina lagenomorpha*? were last recorded about 3 m below the top of Biozone 10, in the Lower Leintwardine Formation of The Whitcliffe (sample W0).

Other taxa recorded from the zone, all of which range through the zone, include *Ancyrochitina ancyrea* (Eisenack), *Calpichitina* (*Calpichitina*) sp. aff. *hemsensis* (Laufeld) and *Eisenackitina intermedia* (Eisenack).

See [‘Distribution of chitinozoa in the Ludlow Series’](#) for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### Occurrence

The base of Chitinozoan Biozone 10 is located between 7 and 8 m above the base of the Lower Leintwardine Formation, in the section above Sunnyhill Quarry.

The top of the zone coincides with the base of Chitinozoan Biozone 11, just below the top of the Lower Leintwardine Formation on The Whitcliffe.

Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).

See: [Chitinozoan Biozone 11, Distribution of chitinozoa in the Ludlow Series, Holostratigraphical chart, Sunnyhill Quarry, The Whitcliffe.](#)

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## Chitinozoan Biozone 11

### Microfauna

The base of Chitinozoan Biozone 11 (Sutherland 1994) was placed at the first appearance of *Gotlandochitina villosa* Laufeld in sample W1, just below the top of the Lower Leintwardine Formation on The Whitcliffe. *G. villosa* ranges into the highest chitinozoan fauna recorded from The Whitcliffe, in the lower part of the Upper Whitcliffe Formation (Biozone 12).

*Calpichitina* (*Calpichitina*) *gregaria*? Paris & Kríz also appears at the base of Biozone 11 (sample W1), and has its last appearance in the Upper Leintwardine Formation, about 0.2 m below the top of the zone on The Whitcliffe (sample W19). It was reported to be a common component of assemblages from Biozone 11 (Sutherland 1994, p. 93). *Ancyrochitina ancyrea* (Eisenack) has its last occurrence at the same level. *Calpichitina* (*Calpichitina*) sp. aff. *hemsiensis* (Laufeld) last appears about 0.3 m below the top of the zone in the Upper Leintwardine Formation of The Whitcliffe (sample W18).

*Eisenackitina intermedia* (Eisenack) ranges through Biozone 11 into Biozone 12.

See ‘[Distribution of chitinozoa in the Ludlow Series](#)’ for ranges of taxa, based on Sutherland’s (1994) data from the type Ludlow Series, and Verniers *et al.*’s (1995) appraisal of global ranges.

### Occurrence

The base of Chitinozoan Biozone 11 is located just below the top of the Lower Leintwardine Formation on The Whitcliffe. Sutherland’s (1994) text-fig. 51 suggests that the base of Chitinozoan Biozone 11 is located at the thin shale that separates beds A and B of Holland *et al.* (1963) in the stratotype for the base of the Upper Leintwardine Formation (locality 3 of Holland *et al.* 1963; locality 3.1b of Siveter *et al.* 1989). Sutherland (1994, p. 93) put the base of the zone 0.84 m below the top of the Lower Leintwardine Formation, but estimates of thickness from Holland *et al.* (1963, fig. 5) suggest a level about 0.6 cm below the top of the formation.

The top of the biozone coincides with the base of Chitinozoan Biozone 12, just below the top of the Upper Leintwardine Formation on The Whitcliffe.

(continued...)

## **Chitinozoan Biozone 11 (continued)**

- Holland, C.H., Lawson, J.D. & Walmsley, V.G. 1963. The Silurian rocks of the Ludlow district, Shropshire. *Bulletin of the British Museum (Natural History)*, Geology, **8**, 95-171, pls 1-7.
- Siveter, D.J., Owens, R.M. & Thomas, A.T. 1989. *Silurian field excursions: a geotraverse across Wales and the Welsh Borderland*. National Museum of Wales, Geological Series No. **10**, Cardiff. 133pp.
- Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).

See: [Chitinozoan Biozone 12, Distribution of chitinozoa in the Ludlow Series, Holostratigraphical chart, The Whitcliffe.](#)

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## Chitinozoan Biozone 12

### Microfauna

Sutherland (1994, p. 93) placed the base of Biozone 12 at the first appearance of *Eisenackitina philipi* Laufeld, just below the top of the Upper Leintwardine Formation on The Whitcliffe (sample W20). The base of Biozone 12 coincides with the base of the *Eisenackitina philipi* Biozone (Verniers *et al.* 1995).

*Gotlandochitina dinhamensis* Sutherland first appears 0.46 m above the base of Biozone 12 in its type section (i.e. at the base of the Lower Whitcliffe Formation, sample W25), and *Gotlandochitina?* sp. A of Sutherland (1994), which appears in Biozone 9, is common throughout the zone. *Eisenackitina intermedia* (Eisenack) and *Gotlandochitina villosa* Laufeld are also present in the highest assemblage recorded from the zone, from the base of the Upper Whitcliffe Formation (sample W45).

See 'Distribution of chitinozoa in the Ludlow Series' for ranges of taxa, based on Sutherland's (1994) data from the type Ludlow Series, and Verniers *et al.*'s (1995) appraisal of global ranges.

### Occurrence

Sutherland (1994, p. 93) placed the base of Chitinozoan Biozone 12 just below the top of the Upper Leintwardine Formation, 0.46 m below the base of the Lower Whitcliffe Formation in its basal stratotype section (locality 3 of Holland *et al.* 1963; locality 3.1c of Siveter *et al.* 1989). Sutherland (1994, text-fig. 52) placed this level in Bed B of Holland *et al.* (1963), but this is evidently a mistake, as Bed D is wrongly identified as Bed C on Sutherland's text-figure, and the thickness of Bed B on the figure (about 0.5 m) far exceeds the thickness of about 0.1 m given by Holland *et al.* The base of Biozone 12 almost certainly lies within Bed C of Holland *et al.* (1963), especially when its position 0.46 m below the base of the Lower Whitcliffe Formation is considered.

The top of the biozone has not been defined; the highest chitinozoans from the type Ludlow area, also attributed to Biozone 12, were collected about 2.4 m above the base of the Upper Whitcliffe Formation in its basal boundary stratotype section (sample W45; Whitcliffe Quarry; Holland *et al.* 1963, loc. 6; Siveter *et al.* 1989, loc. 3.1f). The chitinozoa from this level comprise taxa that are characteristic of the biozone, including *Eisenackitina philipi*, *Gotlandochitina dinhamensis* and *Gotlandochitina?* sp. A, as well as *Eisenackitina intermedia* and *Gotlandochitina villosa* (Sutherland 1994, text-fig. 55).

(continued...)

## **Chitinozoan Biozone 12 (continued)**

- Holland, C.H., Lawson, J.D. & Walmsley, V.G. 1963. The Silurian rocks of the Ludlow district, Shropshire. *Bulletin of the British Museum (Natural History)*, Geology, **8**, 95-171, pls 1-7.
- Siveter, D.J., Owens, R.M. & Thomas, A.T. 1989. *Silurian field excursions: a geotraverse across Wales and the Welsh Borderland*. National Museum of Wales, Geological Series No. **10**, Cardiff. 133pp.
- Sutherland, S.J.E. 1994. Ludlow chitinozoans from the type area and adjacent regions. *Palaeontographical Society Monograph*, London, 1-104, pls 1-18 (publ. No. 594, part of vol. 148 for 1994).
- Verniers, J., Nestor, V., Paris, F., Dufka, P., Sutherland, S. & Van Grootel, G. 1995. A global Chitinozoa biozonation for the Silurian. *Geological Magazine*, **132**, 651-666.

See: [Distribution of chitinozoa in the Ludlow Series, Holostratigraphical chart, The Whitcliffe.](#)

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