

The Festningen section

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The section is named after Festningen ("The Fortress"), a small islet with a lighthouse marking the western approaches to Grønfjorden. The islet is formed by almost vertical indurated Festningen sandstone beds of Cretaceous age (Barremian) that consist of fluviodeltaic deposits, some with large dinosaur footprints.

An 8 km long coastal section from the Precambrian to Cenozoic can be studied along the southern coast of Isfjorden to the east of and around Festningen itself (Fig. 1). The outcrops are within the western fold-belt of Spitsbergen, resulting in steeply dipping to vertical beds. The folding took place during transpressive movements between Greenland and Svalbard in the Eocene prior to the Oligocene opening of this sector of the Norwegian-Greenland Sea. The compressive tectonics involved intense deformation of the shales in the succession, so that significant overthrusting and shortening affected these units. Metamorphic basement forms the westernmost part of the exposures and Lower Carboniferous braided stream conglomerates occur lowermost in the post Caledonian succession. However a gravel filled bay covers most of the Carboniferous to Lower Permian succession; only scattered exposures of carbonates and some remains of collapse breccias representing upper Carboniferous to lowermost Permian evaporites and carbonates occur at the next point; these units are beautifully exposed on the northern coasts of Isfjorden. The Kapp Starostin Formation of Late Permian age is a limestone – chert dominated unit and its lower parts form the next major point. Kapp Starostin itself takes its name from the Pomor Russian Ivan Starostin who spent many of his altogether 39 overwinterings in this area, before being buried nearby in 1826. From base of this unit it is possible to walk five km along well-exposed coastal cliffs (Fig. 2). Harsh autumn storms with rough waves wash the section clean, and in this way we get new, clean exposures every year.

The Festningen section has been a standard reference for Svalbard's geology since early in the last century, and Norwegian expeditions started detailed studies here in 1908. The section was logged in detail and extensive fossil collections were made. These were described in a series of papers during the following 30 years and the results of this

work were summarized by Hoel & Orvin (1937). The area was then somewhat neglected for the following 40 years and sporadic investigations were restricted to partial redefinition of parts of the succession in terms of the lithostratigraphical units introduced in the 1960s throughout Svalbard. In late 1970s studies by the universities of Oslo and Bergen resulted in greatly improved understanding of the depositional environments represented in the succession (Steel & Worsley 1984). More recently a revised lithostratigraphic scheme for the Mesozoic of Svalbard and the Barents Sea also included a revision of the Festningen succession (Mørk et al. 1999). Details from the Festningen Section will be presented in a separate guidebook (Mørk & Worsley 2006).

The 400 m thick Kungurian to Upper Permian Kapp Starostin Formation has bioclastic limestone banks with brachiopods and bryozoans at its base. These limestones grade up into shales with deeper and colder water faunas, including prolific siliceous sponges and bryozoans; spectacular zoophycoid burrows are also common. The high (<70 %) content of sponge spicules in the shales that dominate this unit have produced the distinctive appearance and texture of the resultant "spiculites". These present formidable operational problems – both to walk over and drill through!

These spiculites alternate with sandy silicified limestones in a series of three transgressive regressive sequences in this type section; note that the formation thins dramatically to only a few metres of sandy limestones over regional highs.

The Triassic succession of the Festningen section is represented by five formations, each starting with a major sequence boundary; lower two of these have their type sections along this coast. The shale-dominated lower to mid-Triassic Sassendalen Group is around 700 m thick here.

The 290 m thick basal (Induan) Vardebukta Formation (type section here) is named after the cairn on the coastal cliff within the bay (Vardebukta = Cairn Bay). The aftermath of the late Permian mass extinction can be seen as fossils are sparse in the uppermost Permian spiculitic shales and virtually absent in the lower 100 metres of the soft Vardebukta Fm claystones. Even trace fossils are quite sparse here. The latter are intruded by a

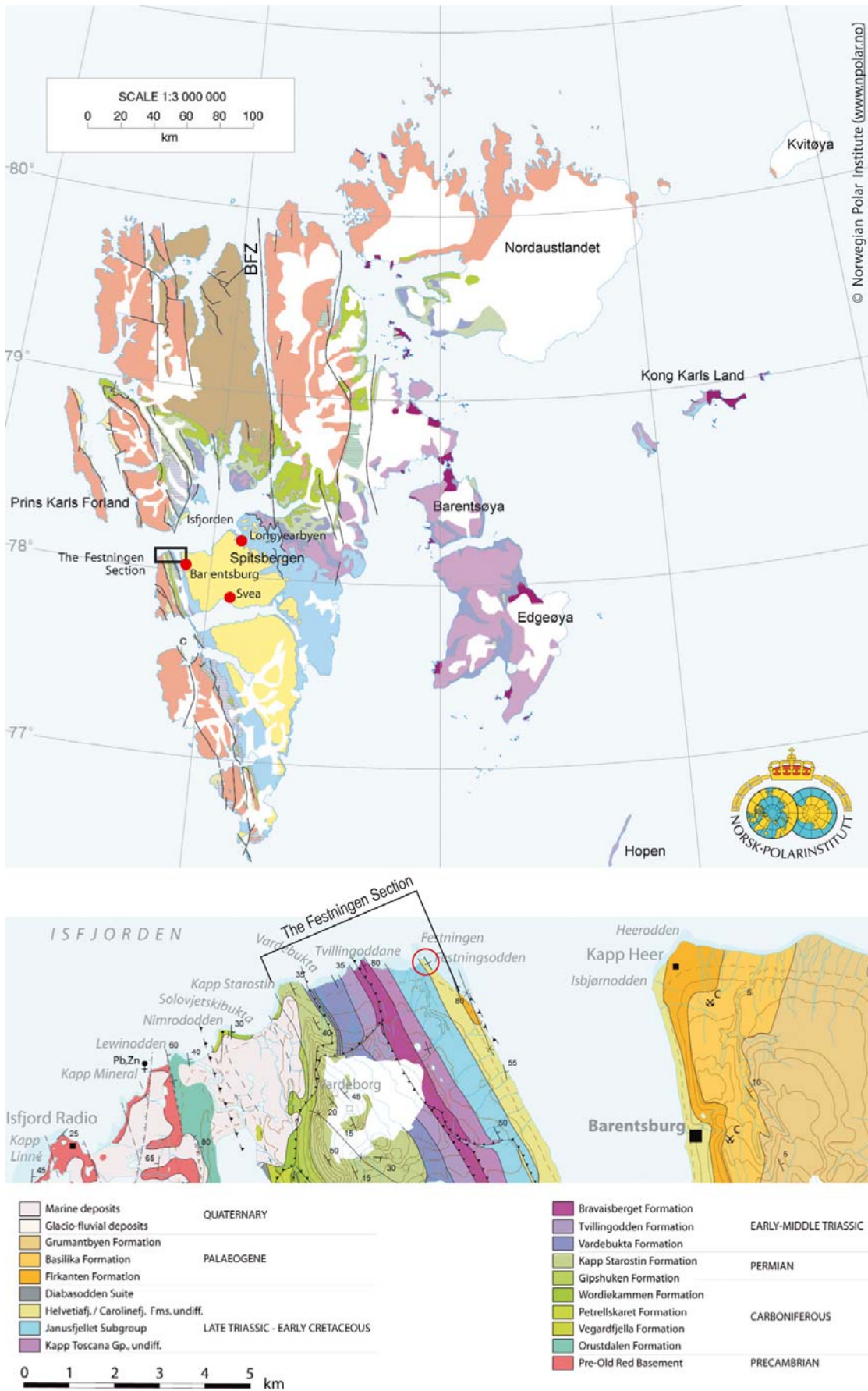


Figure 1. Geological map of Svalbard with the Festningen Section enlarged in the lower part.

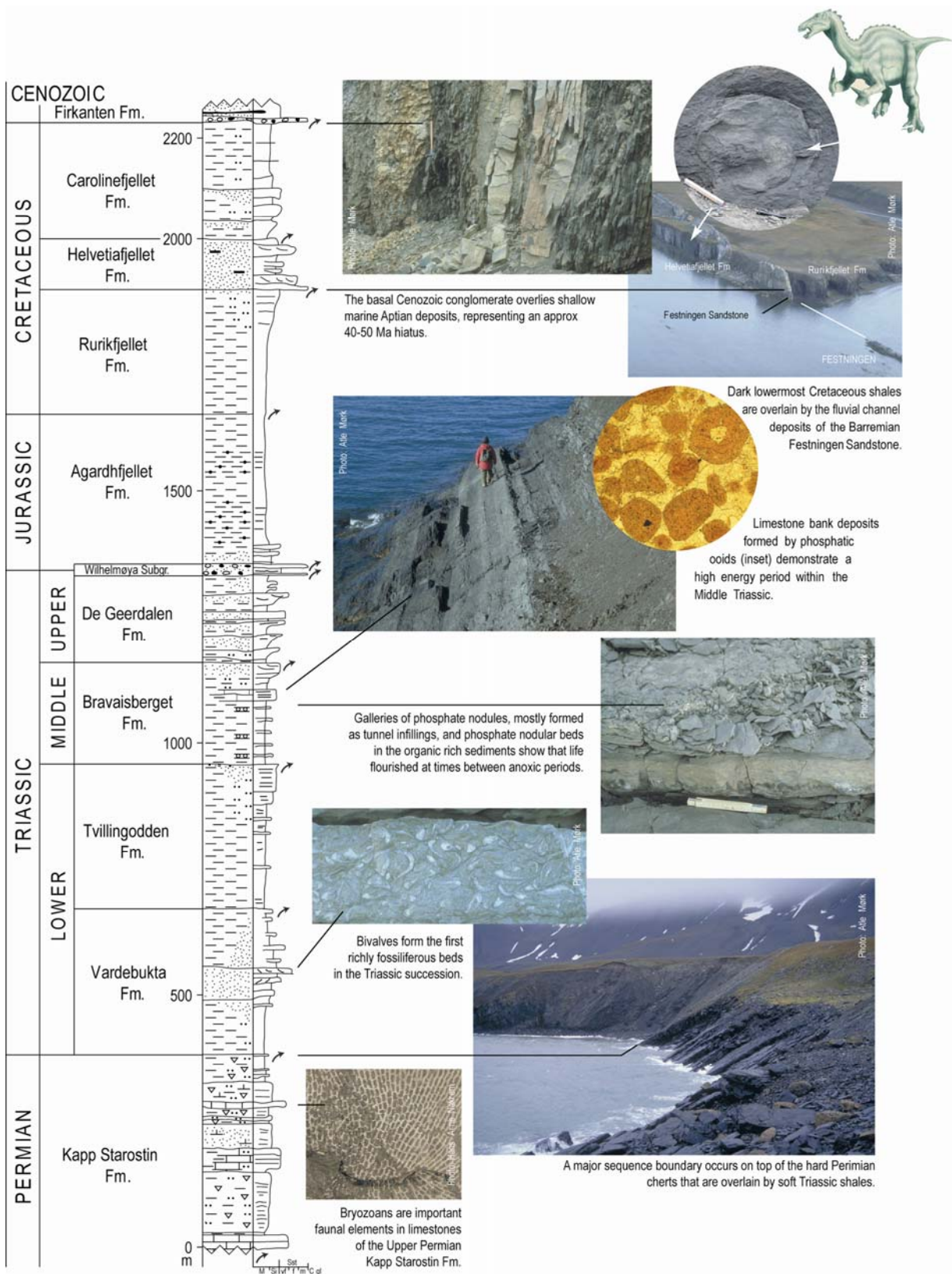


Figure 2. Schematic interpretative section through the sediments from the Late Permian to the base Cenozoic. Thickness values are approximate as strong compression may have taken place in the shaly units.

diabase sill, probably emplaced in the late Jurassic/early Cretaceous. Deep shelf shales with occasional storm siltstones low in the formation grade upwards into massive sandstones and fossiliferous (*Myalina* bivalves) beds with conspicuous *Skolithos* in the shallowest coastal bar. Above this bar complex deepening again occurs, with more shales and siltstones in the upper part of the formation.

The 220 m thick Olenekian Tvillingodden Formation (“Twin Point”, type section here) also represents a major coarsening upward succession. Parallel-laminated beds with sparse fossils and little bioturbation grade up into shallow shelf interlaminated shales and siltstones. Occasional lenticular carbonate concretions may contain well-preserved ammonoids. Interesting assemblages of *Rhizocorallium jenense* in the upper part of the unit indicate improved living conditions (Worsley & Mørk 2001). A topmost bed contains mixed Spathian and Anisian brachiopods and bivalves and represents the basal Anisian transgression.

The Bravaisberget Formation (Anisian-Ladinian, type section at the next fjord to the south) here consists of dark shales at its base with thick calcareous siltstone beds. Poorly preserved ammonoids are abundant. Phosphatic nodules, occurring as *Thalassinoides* tunnel fillings and as nodular horizons (often at the bases of massive siltstone beds) occur repeatedly through the lower part of the formation. Extensive folding has taken place in the dark organic rich shales, making thickness estimates impossible, a rough estimate being around 200 m. Towards the top of the formation thinly laminated beds with abundant phosphatic oolites and microcoquina shell fragments form a few metre thick unit. The microcoquina beds are thought to represent the remains of mass-deaths of juvenile bivalves. The interplay of highly burrowed siltstone beds, galleries of *Thalassinoides* tunnels, organic rich mudstone and these microcoquinas indicate fluctuating oxygen levels during deposition. The upper part of the formation forms the Van Keulenfjorden Member (“Fossesandstein” of early workers) representing shallow, delta top silt- and sandstones deposited above wave base.

A major transgression led to changing sedimentational regimes at the advent of the late Triassic. Over most of Svalbard a prodeltaic shale unit, the Tschermakfjellet Formation, consisting of grey (organic-lean) shales with red weathering siderite nodules, marks the base of the Kapp Toscana Group – here about 300 m thick. The Tschermakfjellet Fm is almost absent at Festningen, and is only represented by a few metres of shale below the De Geerdalen Formation, which has repeatedly small coarsening upwards rhythms from shales to thin sandstone beds interpreted as sand banks and shoals deposited in a moderately deep to shallow shelf. Elsewhere this unit is characterized by

thick delta front and delta plain sandstones. The uppermost 70 m of the formation show greenish and red mudstones indicate restricted (?lagoonal) depositional environments and these are included in the Isfjorden Member. Similar beds are widespread throughout the Barents Shelf and are of early Norian age.

A thin polymict conglomerate containing pebbles of quartz and phosphate forms the transgressive Slottet Bed of the Wilhelmøya Subgroup. This subgroup, here represented by the 18 m thick highly condensed beds of the Knorringfjellet Formation, thickens dramatically towards the East and South, where it contains several sandstone-dominated formations (the main hydrocarbon reservoir units of the southern Barents Sea). The Triassic – Jurassic boundary occurs within this unit, which at its top contains a widespread polymict phosphate nodule containing bed, the Brentskardhaugen Bed or “Lias conglomerate”, with remanié fossils of Toarcian to ? Bajocian age. This bed was not recognized in the Festningen section by early workers but in 1978 we dug it out of the scree in the creek following this geological boundary.

Callovia marine sandstones overlie the conglomerate and initiate a highly tectonised approximately 400 m thick black shale unit, the Janusfjellet Subgroup. Its Jurassic part, the Agardhfjellet Formation, contains abundant organic-rich paper shales, which are elsewhere (also in the subsurface of the western Barents Sea) an excellent source rock for hydrocarbons. Separated by an unconformity the lowermost Cretaceous Rurikfjellet Formation is also organic-rich, but without oil-prone kerogen. This forms a coarsening upward and shallowing succession, in its upper part loaded with characteristic cannon-ball concretions.

Fluvial sandstones of the Festningen sandstone itself follow with a marked erosional contact. Here three thick tributary channels are preserved as near-vertical beds, the lowermost of which has revealed dinosaur footprints of an ornithopod herbivore, previously referred to *Iguanadon*.

These beds belong to the 75 m thick fluviodeltaic Barremian Helvetiafjellet Formation, whose upper parts show a gradual transgression to the shallow marine sandstones lowermost in the Aptian to Albian Carolinefjellet Formation. This 320 m thick unit (thinning to 100 m in Longyearbyen) shows increasing clay content and deeper storm-generated silt- and sandstones upwards. The occurrence of Glendolites indicates significantly cooling water conditions. Only the two lower members of this formation were deposited and/or preserved here, while further south- and eastwards the unit thickens considerably to over 1,000 m in southern Spitsbergen.

A pronounced hiatus separates these Lower Cretaceous shales from the basal conglomerate of the Cenozoic succession. Here a 40 – 50 Ma

duration hiatus demonstrates the regional upheaval of the area during the late Cretaceous. A few metres above the conglomerate, coals have been dug out in a test mine; these belong to the same coal seam mined in Barentsburg on the opposite side of the fjord. Here only a small faulted outlier of this unit is present and the remaining part of the succession is scree-covered, before passing back down again into the Carolinefjellet Formation just a little further south along the coast of Grønfjorden. This completes our 8 km long wander through about 220 Ma of the earth's boreal history!

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THE NEXT CHAPTER

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