Art. XI.—*The Occurrence of Coral Reefs in the Triassic of North America;** by James Perrin Smith.

The occurrence, in the strata of past ages, of reef-building corals of modern groups gives us our best record of climatic conditions in those times. The modern reef-builders are now confined to the tropics, and it is only reasonable to assume that they have always been confined to regions where the waters had a tropical temperature.

No corals of any sort are known as yet in the Lower Triassic, anywhere in the world, although the Hexacoralla must have lived somewhere during that time, since they are known before and after it. In the Middle Triassic of the Alpine province reef-building corals occur, but are not abundant enough to form reefs. They are not yet described from any other region. Towards the end of the Upper Triassic reef-building corals became abundant in the Alps, where they have long been known, and where they formed genuine reefs that had an important influence on the topography. There they extend up to latitude 45° N., showing that in this epoch the Alpine province enjoyed a warm climate. The chief coral zone of the Alpine province occurs in the Noric epoch of the Upper Triassic, not far above the rich ammonite limestone of the Karnic epoch. The occurrence of this same coral fauna, in the same stratigraphic position, in localities far removed from the Mediterranean Region would be ample proof that the favorable conditions were widely distributed over the earth in this epoch. This would also tend to show the probability of the amelioration of the general temperature, at least over the northern hemisphere, during this epoch.

Reef-building corals have been found in the Himalayas in India in the Noric beds, but are not yet described; their evidence as to physical conditions is just as positive, even though we do not yet know by what names they should be called.

In his studies of Triassic stratigraphy in northern California the writer was long ago impressed by the fact that the limestone there resembles coral rock, and fragments were found that suggested remains of corals. Several years ago this was confirmed by the discovery of abundant corals in many places on the limestone ridge between Squaw Creek and Pitt River, and on Cow Creek south of Pitt River. The general section of the Triassic of Shasta County is given below, to show the position of the coral zone.

In the section given above, the thickness of the beds is only approximate, varying from the maximum near the junction of

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Triassic Section of Shasta County, California.

					Thickness
Upper Triassic	Noric	Brock Shales		Black slates, with *Pseudomonotis subcircularis.*	?800 ft.
		Hosselkus Limestone		*Spiriferina* beds, hard siliceous limestone, full of brachiopods.	100 ft.
				Coral zone, with numerous reefs, of Astræidæ, *Isastræa, Stephanocœnia, Astrocœnia, Thamnastræa,* and *Thecosmilia.*	
	Karnic		Zone of *Tropites subbullatus*	*Juvavites* beds, hard limestone, with abundant ammonites, *Juvavites, Gonionotites, Discophyllites, Tropites Telleri, T. laestrigonus,* etc.	50 ft.
				Trachyceras beds, shaly limestone, with *Tropites subbullatus, T. torquillus, T. Dilleri, Discotropites sandlingensis, Paratropites, Trachyceras Lecontei, T. shastense,* etc.	50 ft.
				Halobia superba shales, calcareous shales, full of *Halobia superba,* and a few crushed *Trachyceras.*	100 ft.
				Halobia rugosa slates, black argillites, with *Halobia rugosa,* and crushed *Trachyceras.*	?150 ft.
				Unconformity ?	
Middle Triassic	Muschelkalk	Pitt Shales		Black siliceous shales, altered tuffs, and igneous rocks, with *Ceratites* conf. *humboldtensis, Ptychites, etc.*	?1500 ft.
				Unconformity	
Upper Carboniferous				Nosoni tuffs and shaly limestones, with *Fusulina elongata,* etc.	
				McCloud limestone, with *Fusulina robusta, F. cylindrica,* etc.	

Squaw Creek and Pitt River, to less than half so much on the North Fork, 15 miles to the north, where the limestone almost disappears entirely.

The *Tropites subbullatus* beds are divided into two zones, each about fifty feet thick. In the lower are numerous *Tropites subbullatus, T. torquillus, T. Dilleri, T. Morloti, T. fusobullatus, Discotropites sandlingensis, Trachyceras Lecontei, T. shastense, Arcestes pacificus, Clionites, Halobia superba,* and many undescribed species of *Tropites, Trachyceras,* etc.

In the higher division, the *Juvavites* or *Atractites* beds are

many, *Juvavites subinterruptus*, *J. subintermittens*, *J. Edgari*, *Tropites laestrigonus*, *T. Telleri*, *Homerites semiglobosus*, *Discotropites Theron*, *D. Laurae*, *Pinacoceras rex*, *Margarites senilis*, *Gonionotites*, *Metasibirites*, *Choristoceras*, and many other species, new and old, *Tropites* of the group of *T. Telleri*, *Discotropites*, of the group of *T. Laurae*, *Atractites* and *Dictyoconites*.

A few feet above the highest *Juvavites* beds lies the coral zone with reefs made up chiefly of *Astraeidae*, *Isastraea profunda*, *Phyllocoenia* cf. *decussata*, *Montlivaultia* cf. *Mojsvari*, *Thecosmilia* cf. *fenestrata*, *Stephanocoenia* cf. *juvavica*, *Thamnastraea* cf. *rectilamellosa* *Spongiomorpha* cf. *ramosa*, etc.

This coral zone was found from near Pitt River, east of DeLamar, northward to the North Fork, always in the same horizon, between the *Tropites* limestones and the *Pseudomonotis* shales.

A few miles south of Pitt River, near the junction of Cedar Creek with Little Cow Creek, the Hosselkas limestone outcrops again, and the coral zone is here well developed. The thickness is not so great as north of Pitt River, being reduced to not much more than one hundred feet, the *Tropites* beds having almost disappeared. Here the writer found in the coral zone banks or reefs of *Thecosmilia* cf. *fenestrata*, *Isastraea profunda* Reuss, *Stephanocoenia* cf. *juvavica*, *Latimæandra* cf. *eucystis*, and *Thamnastraea* cf. *rectilamellosa*.

At this locality, as on Squaw Creek, the coral zone lies well up in the Hosselkus limestone, and below the *Pseudomonotis* shales.

In the Blue Mountains of northeastern Oregon, in Baker County, at Martin's bridge, near the junction of Paddy Creek with Eagle River, the writer discovered in 1908 a small coral reef in the Upper Triassic limestones, of which a section is given below.

It will be noted that this section is entirely different, in the lithologic sequence, from that of Shasta County, California. Nothing lower than the *Halobia* shales was found, and the writer could not determine just what part corresponded to the Hosselkus limestone, since the *Tropites* beds were not exposed, if they are present in that region. Nor could the *Pseudomonotis* shales be found above the coral zone, probably being represented by the barren limestone. The lower shales, with *Halobia* cf. *superba*, were also found at the junction of the two forks of Eagle River, at Anthony's hydraulic mine, but there the limestones that should contain the coral reef are crystalline, and the fossils destroyed. Massive limestone is abundant on the North Fork of Eagle River, but they are everywhere changed to marble.

Section on Eagle River, Baker County, Oregon.

		Thickness
Upper Triassic	Massive limestone without visible fossils.	60 ft.
	Dark brown argillaceous shales, with *Halobia* cf. *austriaca*, and other species of *Halobia*, and *Daonella ?*	100 ft.
	Thin bedded limestone, with banks of corals, *Thecosmilia norica Frech*, *Spongiomorpha* cf. *acyclica* Frech, *Montlivaultia norica Frech*, *Heterastridium conglobatum* Reuss.	40 ft.
	Barren shales.	300 ft.
	Massive limestone without fossils.	100 ft.
	Calcareous shales, with *Halobia* cf. *superba*, *H.* cf. *salinarum*, *H.* cf. *austriaca*, *Dittmarites* sp. ? etc.	30 ft. visible

Some years ago Mr. H. W. Turner discovered some corals in limestone in Dunlop Canyon, Pilot Mountain, near Mina, Esmeralda County, Nevada. These were sent to the writer, who pronounced them Jurassic, as reported by J. E. Spurr* upon this identification. A recent examination of these corals has shown them to be more probably of Upper Triassic age, which is in perfect accord with the stratigraphy. The species determined are: *Montlivaultia* cf. *marmorea*, *Astrocoenia* cf. *Waltheri*, and *Pentacrinus* sp. indet. The two species of coral are well known forms in the Noric beds of the Alps, and *Astrocoenia Waltheri* occurs also in the Noric coral zone of Shasta County, California. The Lower and Middle Jurassic of the Great Basin area are not known in the coral-reef facies anywhere.

A few years ago Dr. G. C. Martin, of the U. S. Geological Survey, discovered in the region of Cook's Inlet, Alaska, some coral-bearing limestones. Among the specimens sent by Dr. Martin from this locality the writer has determined: *Isastraea* cf. *profunda*, *Thecosmilia* cf. *fenestrata*, *Phyllocoenia* cf. *decussata*, *P.* cf. *incrassata*, *Astrocoenia* cf. *Waltheri*, *Montlivaultia* cf. *Mojsvari*, and *Spongiomorpha* sp. indet.

This coral fauna is undoubtedly the same as that in the lower Noric zone of Shasta County, California, and has several species in common with that fauna.

This discovery of reef-building corals in Alaska extends their range northward from 45° in the Alps, and in the Blue Mountains of Oregon, to 60° N. Lat. The coral zone in California, Oregon, Nevada, and Alaska belongs to the same hori-

* Bull. 208, U. S. Geol. Survey, p. 102, 1903.

zon, and contains the fauna of the classic Zlambach beds of the Fischerwiese in the Tyrolian Alps, that is of the Noric horizon of the Upper Triassic.

The group of Astraeidae is abundant in all these localities, except in the Blue Mountains, and since they are still important reef-builders, and now confined to the hottest parts of the tropics, where the temperature does not fall below 74° F., it is reasonable to suppose that in Triassic time they lived under approximately the same conditions. This makes it probable, if not certain, that the sea had a tropical temperature up to 60° N. Lat., at least in the Pacific Ocean.

Speculations as to ancient temperatures of the sea are interesting, but of much more importance to geologists is the fact that this Noric coral fauna gives us a new and distinct benchmark, which in its marked characters and wide distribution equals that of the zone of *Tropites subbullatus*, and enables the positive correlation of strata that heretofore have been a puzzle to stratigraphers.

Stanford University, California.