AN INVESTIGATION OF THE TYPE LOCALITY OF THE ASTORIA FORMATION

by

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James F. Seitz

T A B L E   O F   C O N T E N T S

LIST OF PLATES

AN INVESTIGATION OF THE TYPE LOCALITY OF THE ASTORIA FORMATION

The middle Miocene section of Tertiary marine deposits in the western part of Washington and Oregon for many years has been known as the Astoria formation. Its lithology varies from fine marine shales to coarse sandstone and in certain areas includes extensive basaltic flows. The Astoria formation in Oregon occupies an area approximately forty miles in width along the Pacific Coast from Coos Bay northward to the Columbia River. In Washington the formation occurs in a series of downfolded areas between the southern part of the olympic Peninsula and Columbia River. These downwarps of the marine Astoria sediments extend sixty miles inland from the coast in contrast to the more limited extent noted in Oregon. The deposits range in thickness from 1,000 feet to 5,000 feet (Weaver, 1937, p. 10).

The type locality of the Astoria formation is in the city of Astoria, Oregon on the south side of the Columbia River six miles upstream from its mouth. The type section extends five miles along the bank of the river from Smith Point at the west end of Astoria to Tongue Point just east of the city. The exposures first described occurred in a now-concealed bluff along the shore of the river. The strata of this section dip southward and consist of sandstone, alternating beds of sandstone and shale, arenaceous shale, and shale exposed in sequence upward from the shore to the crest of Coxcomb Hill.

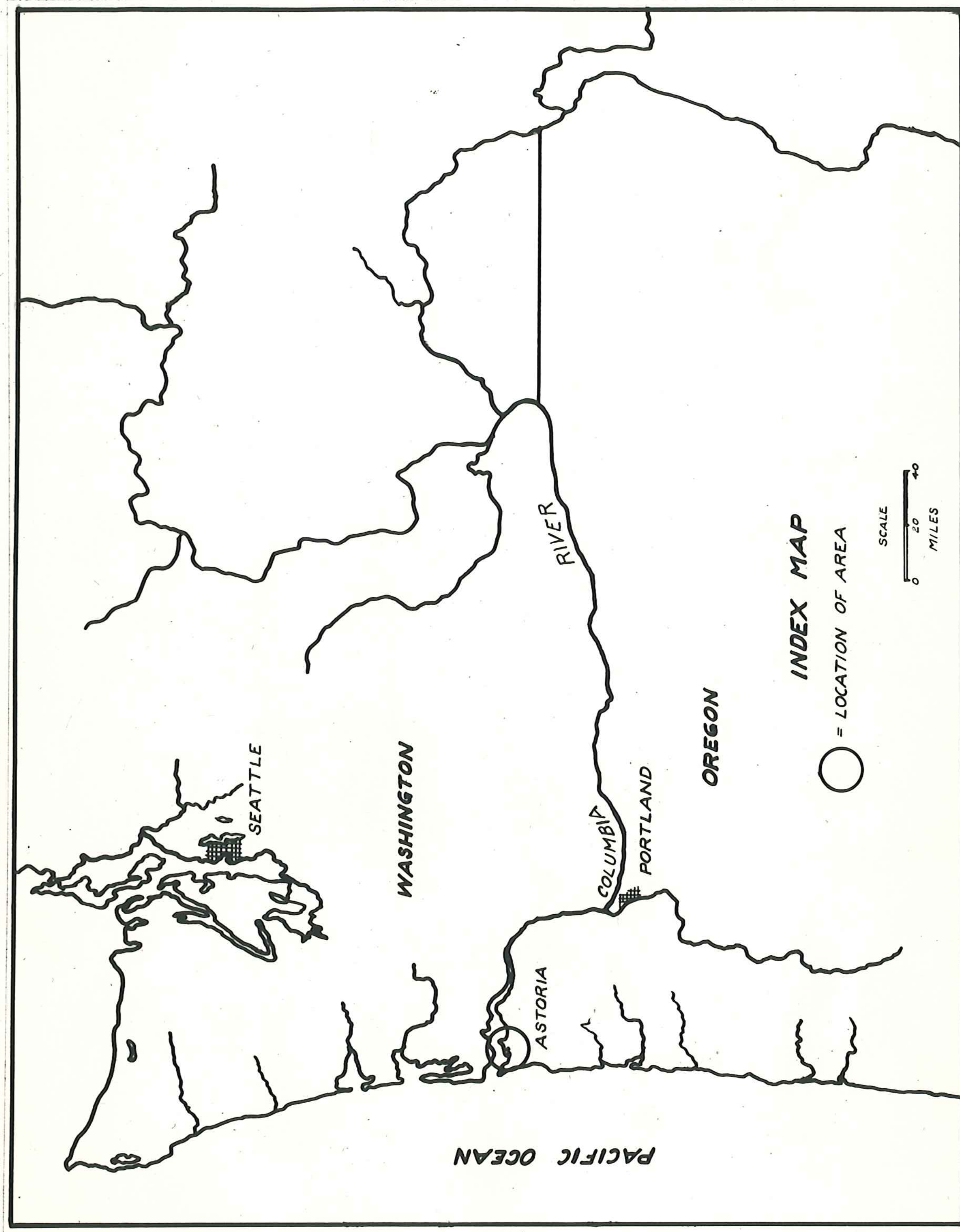

SEATTLE
WASHINGTON
COLUMBIA RIVER
PORTLAND
OREGON
ASTORIA
INDEX MAP
= LOCATION OF AREA
SCALE
0 20 40
MILES
PACIFIC OCEAN

PLATE I

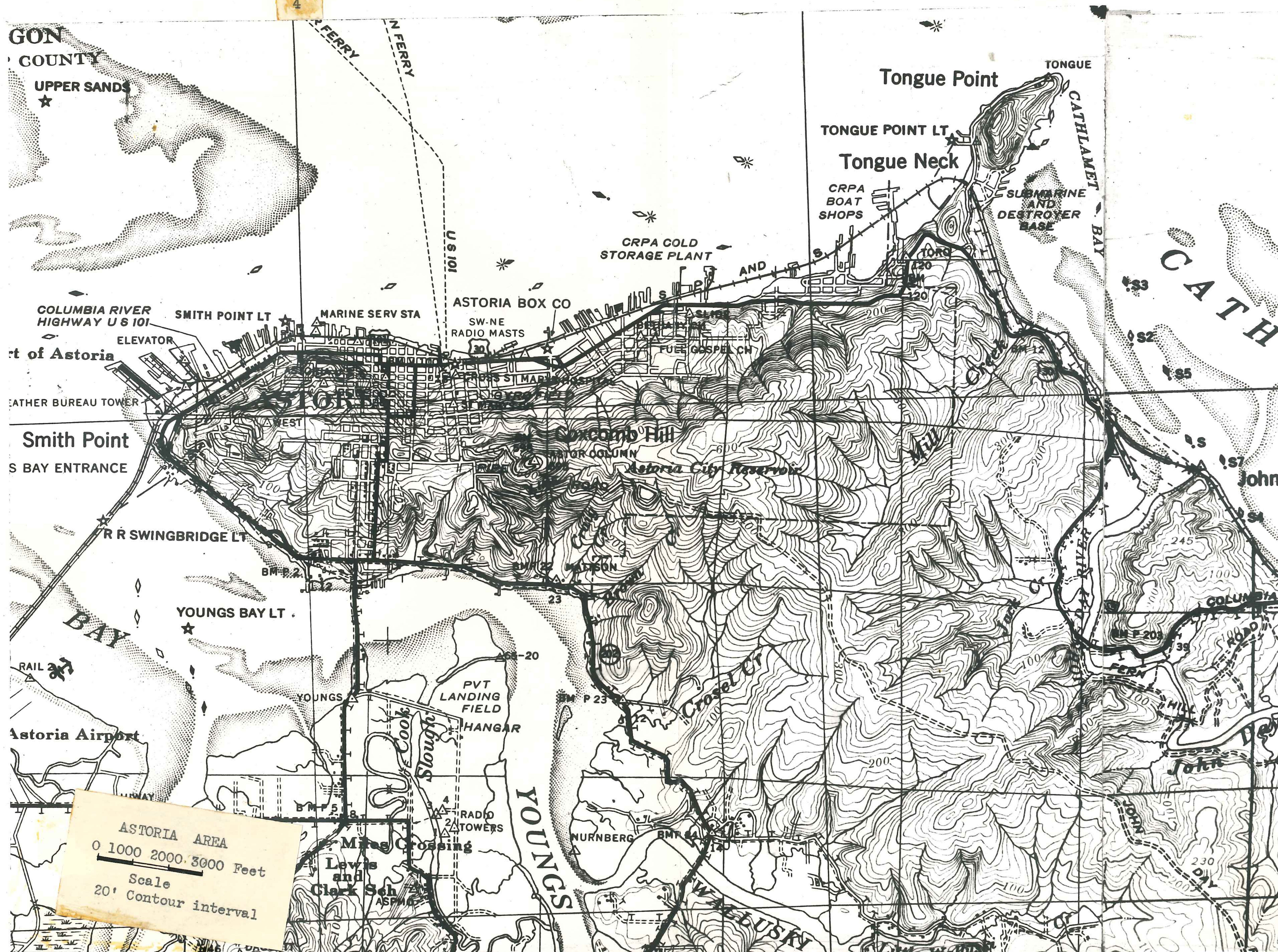

GON
COUNTY
UPPER SANDS
FERRY
FERRY
US 101
Tongue Point
TONGUE
TONGUE POINT LT
Tongue Neck
CATHLAMET BAY
CRPA BOAT SHOPS
SUBMARINE AND DESTROYER BASE
CRPA COLD STORAGE PLANT
S P AND S
CATH
COLUMBIA RIVER HIGHWAY U S 101
SMITH POINT LT
MARINE SERV STA
ASTORIA BOX CO
SW-NE RADIO MASTS
ELEVATOR
rt of Astoria
FUEL
GOSPEL CH
EATHER BUREAU TOWER
Smith Point
S BAY ENTRANCE
Coxcomb Hill
ASTOR COLUMN
Astoria City Reservoir
Mill Creek
John
R R SWINGBRIDGE LT
BM P 2
YOUNGS BAY LT
BAY
RAIL
COLUMBIA
FERN HILL ROAD
John Day
Crosel Cr
YOUNGS
PVT LANDING FIELD
HANGAR
Astoria Airport
RADIO TOWERS
Miles Crossing
Lewis and Clark Sch
NURNBERG
WALLUSKI
YOUNGS
Little Walluski
ASTORIA AREA
0 1000 2000 3000 Feet
Scale
20' Contour interval

PLATE III

GEOGRAPHY

The area investigated extends six miles from Smith Point on the west to John Day Point on the east and for six miles from Tongue Point on the north to the Walluski River on the south. This area is almost completely circumscribed by tide level water with the Walluski and Youngs River on the south, Youngs Bay on the west, the Columbia River on the north, and Cathlamet Bay and the John Day River on the east.

In the north part of the area an elongate crescent-shaped hill with a maximum altitude ranging from 500 to 600 feet extends from Smith Point to Tongue Point, sloping to sea level at either end. A lower ridge with a northwest-southeast trend branches from the central part and extends through the southeast corner of the area. The topography of the area varies from vertical cliffs in the basalt on Tongue Point to rolling hills along the Walluski River with a prevailing steep hilly terrain. Some of the slopes, especially on the north side of the main hill, have concave profiles which give evidence of extensive landsliding which is typical of the area. Bluffs up to 100 feet high are formed in sandstone along the Youngs and the John Day Rivers.

The annual rainfall in the region exceeds 70 inches. This, coupled with the mild year around temperatures, results in a dense, luxuriant vegetation which completely covers all areas. Douglas fir is the predominant tree while alder, devils club, blackberry, and other similar shrubs grow rankly in the continually wet, moldy forest.

CULTURE

Astoria was first settled in 1811 as a fur trading post for the John Jacob Astor Fur Company and has been inhabited continually since that time.

PLATE IV

View to the south from Coxcomb Hill. Southern part of area and Youngs River are in the foreground, Saddle Mt. in the background 20 miles south.

PLATE V

View to the northeast from hill above Smith Point showing amount of construction and filling along the waterfront.

The city has railway, highway, and steamship connections to the south, east, and north. The original precipitous shore along the Columbia River was not well suited to the commercial needs of the inhabitants of Astoria so gradually the waterfront area has been filled in to supply a level area and facilitate commerce. In the process of filling in and building out the waterfront, all the original exposures studied by the earlier geologists have been covered over so as to prevent their restudy by present day geologists.

HISTORY OF PREVIOUS WORK

Information concerning the Tertiary rocks at Astoria was obtained by members of the United States Exploring Expedition, 1838-1842, under the command of Captain Wilkes, U.S.N. One of the ships of the expedition went aground off the mouth of the Columbia River in 1841 and Professor James Dwight Dana, geologist for the expedition, was stranded in Astoria by this shipwreck. While awaiting rescue, Dana studied the outcrops on both sides of Columbia River in this region and collected fossiliferous concretions which had fallen on the Astoria beach from the sandstone and shale bluffs above. Dana (1849, p. 651) described the conditions as follows:

> "In many localities the argillaceous shale contains nodular concretions of limestone. These concretions are often very regularly spherical and vary from half an inch to six feet in diameter, though if exceeding a foot the form is more irregular. The concretions often contain a fragment of wood, a fossil shell, a crab's leg or bones of fish. Fossils rarely occur in the shales where these concretions are found, except they are inclosed in some of the concretions."

These fossils were sent east to J. A. Conrad for identification. In his report, Dana (1849, p. 659) quotes Conrad regarding the age of these fossils:

Dall and Harris (1892, p. 223) published a report in which they described the Astoria group as containing two distinct members; namely, the Astoria shale and the Astoria sandstone, both Miocene in age. The Aturia bed they considered to be Eocene. They were the first to recognize that the shale and sandstone represented merely fluctuating conditions of deposition rather than separate times and conditions of deposition. As the other geologists before them, they placed the sandstone member stratigraphically above the shale. Their evidence for this sequence was based upon the similarity between the sand grains in the Astoria sandstone on the north side of the Columbia River, and in the many sandstone dikes which transect the Astoria shale and presuming the dikes had been filled from above they concluded the sandstone lay above the shale. Dana had previously made the same error. This line of reasoning has now been invalidated by proof that the dikes were injected from beds below the shale.

J. S. Diller (1897, p. 469) accepted this assumption in regard to the relative position of the sandstone and shale. He dated the sandstone as Miocene but considered the age of the shale as doubtful though necessarily older. He accepted this sequence of strata in face of the fact that he recognized the injection origin of the sandstone dikes and how this invalidated Dana's use of the dikes as evidence of the upper position of the sandstone.

Following this W. H. Dall (1898, p. 334) published a correlation table which assigned the Aturia bed and the Astoria shale to the Oligocene and the Astoria sandstone to the Miocene. This was the first use of the term Oligocene on the Pacific Coast and as a result Astoria became an important locality for the Oligocene on the North Pacific Coast.

R. Arnold and H. Hannibal (1913, p. 577) proposed that the name Astoria series be applied to the beds at Astoria. They considered the age to be Oligocene.

B. L. Clark (1918, p. 56) visited the area in 1917 and the following year published a report stating that the Astoria beds should not be considered as the type Oligocene of the Pacific Coast because the beds were of Miocene age. This is the first report to state that Aturia angustata survived into the Miocene.

H. V. W. Howe (1922) mapped the formations in the Astoria area in 1921 and came to the conclusion that the presence of sandstone beds both above and below the shale had confused the men who had worked there previously into thinking there was one sandstone bed which overlay the shale. The fossiliferous sandstone referred to by all previous geologists was proven by Howe to underlay the now-exposed shale. Since the sandstone had already been accepted by Diller, Dall, and others as being Miocene, this definitely set the time of deposition of the shale also as Miocene.

Howe considered that the earlier investigators were mistaken when they referred his lower sandstone as overlying the shale. In doing so he overlooked the fact that a shale bed does lie below the lower sandstone but is now concealed. Clark (1918, p. 56) refers definitely to this bed in the following statement:

> "The black shales below this fossiliferous sandstone have been referred to the Oligocene by Dall."

The sandstone to which he refers could not have been Howe's unfossiliferous upper sandstone. Further on in the paragraph Clark states the case even more definitely:

"At the present time the outcrops of these lower shales, from which originally the so-called Oligocene fossils were obtained, have been covered by sand which was pumped in from the river during the dredging of the channel and it is impossible to get more faunal evidence as to the age of the beds."

Clark thought the fauna which had been described from this lower shale could be assigned to the Miocene rather than the Oligocene as Dall had done. Therefore Howe's failure to recognize the presence of this lower shale does not affect any age considerations. However this oversight does omit the presence of an important member.

Dr. C. E. Weaver (1937) subsequently accepted the Astoria formation as representing mid-Miocene deposition in the northwest area.

Official recognition of this dating of the Astoria formation was given by the Western Cenozoic Sub-Committee of the National Research Counsul (1944, p. 596) in their report on "Correlation of the Marine Cenozoic Formations of Western North America", in which the Astoria formation is placed as contemporaneous with the Temblor formation of California and equivalent to Helvetian time in the international time scale.

METHOD OF INVESTIGATING THE PROBLEM

The method of study was determined by conditions encountered in the area. Natural exposures of rock are non-existent except in isolated places along the four rivers which roughly bound the area. This condition is due to both the rapid disintegrating qualities of the readily weathered shale upon exposure to this humid climate and to the rank growth of vegetation which covers the area. The only other sources of exposures are excavations made in process of constructing roads and buildings.

The problem of correlating isolated exposures was complicated by the nature of the shale which has readily yielded to warping, faulting, and slumping. The concave profiles encountered on some hillsides and the hummocky appearance of the topography are due to these causes. Slumping is prevalent and affects the shale to considerable depths.

The base map used in connection with this study was a 10 times enlargement of the Army Engineer topographical map. The Army Air Corps and the Navy aerial photographs were used to supplement the map.

The data obtained in many exposures are not reliable. As an attempt to discard unreliable data, all strikes and dips were plotted on a structure map and from this the predominant trends were determined and utilized.

STRATIGRAPHY

The knowledge of the stratigraphy of the Astoria type section has developed as new exposures have become available for study.

Early geologists recognized a shale and an overlying sandstone bed but held varying opinions as to the time relationship between the two. Dall (1892, p. 224) was the first to state that the shale and sandstone represented different facies of the same general time and depositional conditions.

As exposures higher up in the city became available for study and the lower exposures were concealed by filling, the shale below the sandstone was confused with the shale above. Outcrops of a sandstone member above this upper shale bed further complicated the situation because it was confused with the lower sandstone.

With the purpose of determining the stratigraphic sequence of the Astoria formation type section, H. V. Howe (1926, p. 295-300) made a study of all exposures available in the vicinity of Astoria in 1922. He concluded from his study that the type section of the Astoria formation is composed of three lithologically distinct units; namely, the lower sandstone, the shale, and the upper sandstone. This conclusion is correct for the beds now exposed but as mentioned previously he failed to note the presence of a now-concealed shale member below the lower sandstone. If this lower shale is of Miocene age as Clark (1918, p. 56) regarded it, then it should be added as another member to the type Astoria section. If it is Oligocene, Howe's definition of the Astoria formation is complete as it stands.

LOWER SANDSTONE

The name lower sandstone includes the layers of sandstone and alternating sandstone and shale which outcrop at the type Astoria locality on the north side of the Astoria hill. The western most exposure of this member occurs at 5th and Commercial Streets and the eastern most exposure at 11th Street and Franklin Avenue.

Before the process of building up the waterfront had progressed to its present state, the bed was exposed on the west as far as Bond and Hume Streets and on the east to the foot of 19th Street (Howe, 1926, p. 298). The prevailing dip of the beds is to the south while the strike ranges from northwest-southeast at the western exposure to a nearly east-west dip eastward as the beds follow the curve of the syncline.

The stratigraphically lowest exposure of the lower sandstone occurs on the south side of Commercial Street 50 feet west of the intersection with 5th Street. The presence of sandy shale in the lowest part of the lower sandstone suggests the possibility of a shale bed below the sandstone.

Twenty-five feet above street level the lowest exposure is a sandy shale. This grades upwards into an argillaceous medium to fine grained brown rather massive sandstone which contains thin beds of sandy shale. Fossils, especially gastropods, are to be found here but are so decomposed by weathering that they crumble when handled.

The next stratigraphically higher section of the lower sandstone is exposed in a 40 feet high vertical cliff located 50 feet west of the corner of Exchange and 7th Streets (see map on Plate III, photograph on Plate VI). The bottom 20 feet consists of 45 regular alternating beds of grey

PLATE VI

Exposure of lower sandstone. View looking southeast from 50 feet west of the intersection of 7th and Exchange Streets.

sandy shale. In this lower 20 feet the shale becomes progressively more dominant upwards. At this level the sandstone becomes more prominent but less so upwards. The upper part of th.. exposure is composed almost entirely of shale. An almost vertical sandstone dike intersects all beds exposed.

Two exposures of the lower sandstone occur on the 11th Street between Franklin and Grand Avenues. On the west side of 11th Street 50 feet south of Franklin a 20 feet high section of alternating sandstone and shale is exposed (see Plate VII). The individual beds in the lower part are about six inches thick and are composed of greyish green coarse sandstone and black shale. In the upper part of the exposure the beds are thinner and the shale beds are replaced by fine grained argillaceous sandstone beds. At the top is a six inch stratum composed of hard concretions. In the boundaries between beds from the 10th to the 12th lamination down from the top are concentrated masses of small pelecypods. Threading obliquely through the beds and deforming them is a sandstone dike (center of Plate VII). Two hundred feet south of this exposure and forty feet higher stratigraphically is an eight feet exposure of eight inch beds of hard greenish grey sandstone laminated with two inch beds of finer grained sandstone between. This is the highest observed section of the lower sandstone.

In summary, the lower sandstone is characterized by alternating strata of sandstone and shale. The base part possibly represents a transition upward in stratigraphic sequence from sandy shale to rather massive sandstone exposed at 5th and Commercial Streets. The upper part is a transition from the laminated beds to sandy shale. The lower sandstone has a minimum thickness of 110 feet.

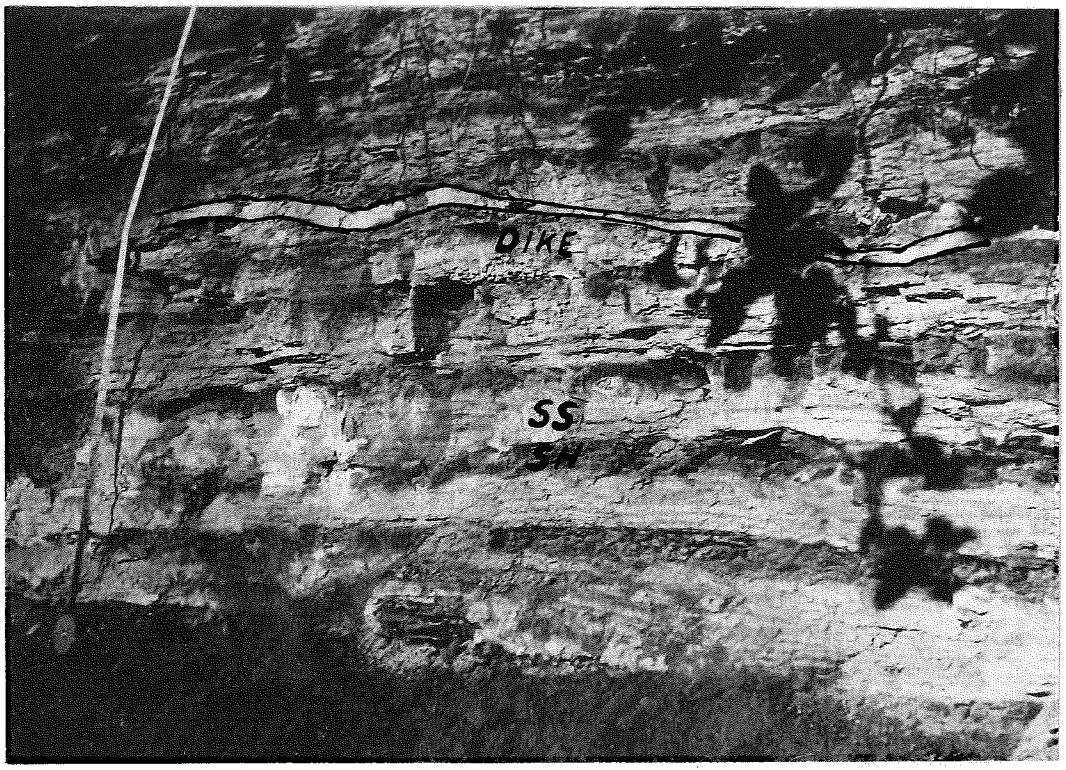


PLATE VII

Exposure of lower sandstone on the east face of bank on the west side of 11th Street 50 feet south of Franklin Avenue. A thin, almost flat lying sandstone dike is visible in the middle of the photograph.

SHALE

The term shale includes the beds of shale and sandy shale which extend stratigraphically from the upper contact of the lower sandstone to the lower contact of the upper sandstone (see Plate VIII). Discontinuous exposures disclose its presence in almost all the area from Smith Point to Tongue Point on the north side of the central ridge and in certain areas south of the ridge to the Walluski River.

The shale ranges in lithology from a sandy shale to shale fine enough in composition to form a temporary suspension in water. Weathering of the shale results in a surface mantle of clay. Where the shale is the surface rock, extensive slumping is the typical feature of the terrain. This action is particularly noticeable in the city where sections of the streets have suddenly dropped away ten feet or more below street level. In the areas where slumping is more active, the paving and sidewalks have a rolling surface from movement in the subsurface.

The appearance of the shale is by no means uniform but varies widely. A general description as a blue-black, well bedded shale would cover most of this member. Departures from this over-all description can best be illustrated by describing a few exposures which differ in appearance.

Black, massive, indurated shale lacking all evidence of bedding in a vertical section at least 20 feet thick can be seen on the south side of Alameda Avenue 240 feet west of Melbourne Street. Immediately above interbedded layers of white sandstone indicate the attitude of the beds.

Brown sandy shale is exposed on the north side of Grand Street between 10th and 11th Streets. Shaly sandstone which is near the contact with the lower sandstone grades upwards into a sandy shale quite different

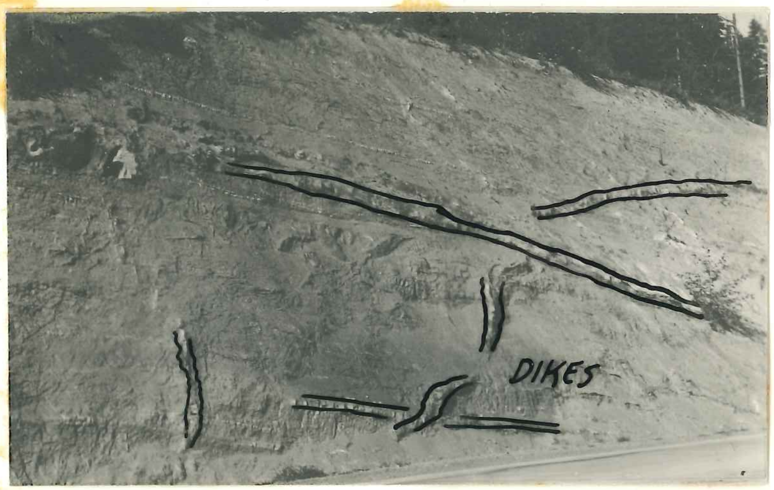


PLATE VIII

Exposure of shale and transecting sandstone dikes. View to south in U. S. 30 Highway cut south of Tongue Point.

from the main mass of fine silty shale. Bedding is not sharply demarcated, though evident.

Buff colored shale occurring so perfectly bedded that smooth, tabular sheets about an inch thick may be readily removed intact is exposed along the north side of the Astor Column road on the first switchback to the west from the top of Coxcomb Hill.

Shale containing enough limey material to color white a three feet thick bed can be seen just south of the pump house on the west side of the water line road which connects the new (1947) Navy housing project with the John Day Pipe Line road.

In general, the shale in the upper part of the shale member varies from brown to buff while the lower part is generally blue and black. Under any circumstances, the color of the shale provides no reliable criteria upon which to correlate beds.

One distinctive feature of the shale is the large number of concretionary beds within it. At almost every exposure concretions appear, usually aligned in short discontinuous beds. These concretions range from an inch diameter up to large boulders in size and vary from soft to extremely hard. Most of the fossils originally collected at Astoria were preserved in concretions which had weathered out of their containing beds and rolled down on to the beach. However very few of the concretions now exposed contain fossils so possibly the fossiliferous concretions occur on lower beds which are now concealed. An indication of their composition is noted by the fact that the early settlers burned them as the only local source of lime.

A one foot thick bed of cherty rock which emits sparks when struck with steel outcrops along the Navy pipe line road. This is the only exposure of the bed in the area.

A band of bright yellowish green sand in the shale has been used as a horizon marker (Howe, 1926, p. 300). The best place to observe this at present is on a bluff on the northwest corner of 10th Street and Harrison Avenue where it occurs in the shale 7 feet below a fossiliferous concretionary bed. (See faunal locality 228 on columnar sections, Plate X). An almost identical greensand bed appears near the top of a cut on the south side of Harrison Avenue between 8th and 9th Streets. Since this bed is stratigraphically 200 feet above the greensand at 10th and Harrison, a possibility of confusion exists as to correlation on the basis of greensand beds.

Fossils are in general scarce in the shale. Where they do occur great numbers may be concentrated in a thin bed. Such a concentration occurs in and bordering the concretionary stratum seven feet above the greensand bed previously mentioned at 10th Street and Harrison Avenue. Here large numbers of Palliolum (Delectopecten) peckhami (Gabb) are found both in the concretions and in the adjacent shale. Foraminifera are also extremely abundant at this locality. On the west side of 9th Street 100 feet south of Harrison foraminifera are exceptionally abundant in the shale.

UPPER SANDSTONE

The member termed upper sandstone is exposed along the John Day River, the Youngs River, the Walluski River, the John Day Pipe Line Road, and in most of the south half of the area. Howe (1926, p. 300) first defined the member but said little about it other than mentioning two exposures and the fact that it is unfossiliferous, and remarkably lacking in bedding.

The sandstone is uniformly composed of medium to coarse grains of quartz with a noticeable abundance of mica. It ranges in color from grey, white, yellow, and brown to bright oxide red depending upon the iron associated with it. In many exposures, diffusion of the staining elements has taken place similar to the process involved in forming Liesegang rings with a resulting banding of colors, usually red and white, in complex and beautiful patterns. The photograph on Plate IX illustrates the patterns formed but not the colors. Associated with the sandstone in many places are fragments and blocks of shale which have definitely not been bedded contemporaneously with the sandstone but have been broken and introduced later as the sandstone bed was being formed.

No estimate of the thickness of the sandstone can be made as no bedding, strike, or dip was observed in any of the numerous exposures studied. Stratigraphically it extends from the shale to the surface. No other beds lie above it in this area. From all appearances, it varies in thickness from one place to the next.

In the few places where the contact of the sandstone with the shale can be seen, the succession is not clearly defined. This feature is discussed further in the section referring to the origin of the upper sandstone.

PLATE IX

Exposure of upper sandstone. View to the east of cut on road along the Walluski River five miles south of Little Walluski River bridge.

COLUMNAR SECTIONS

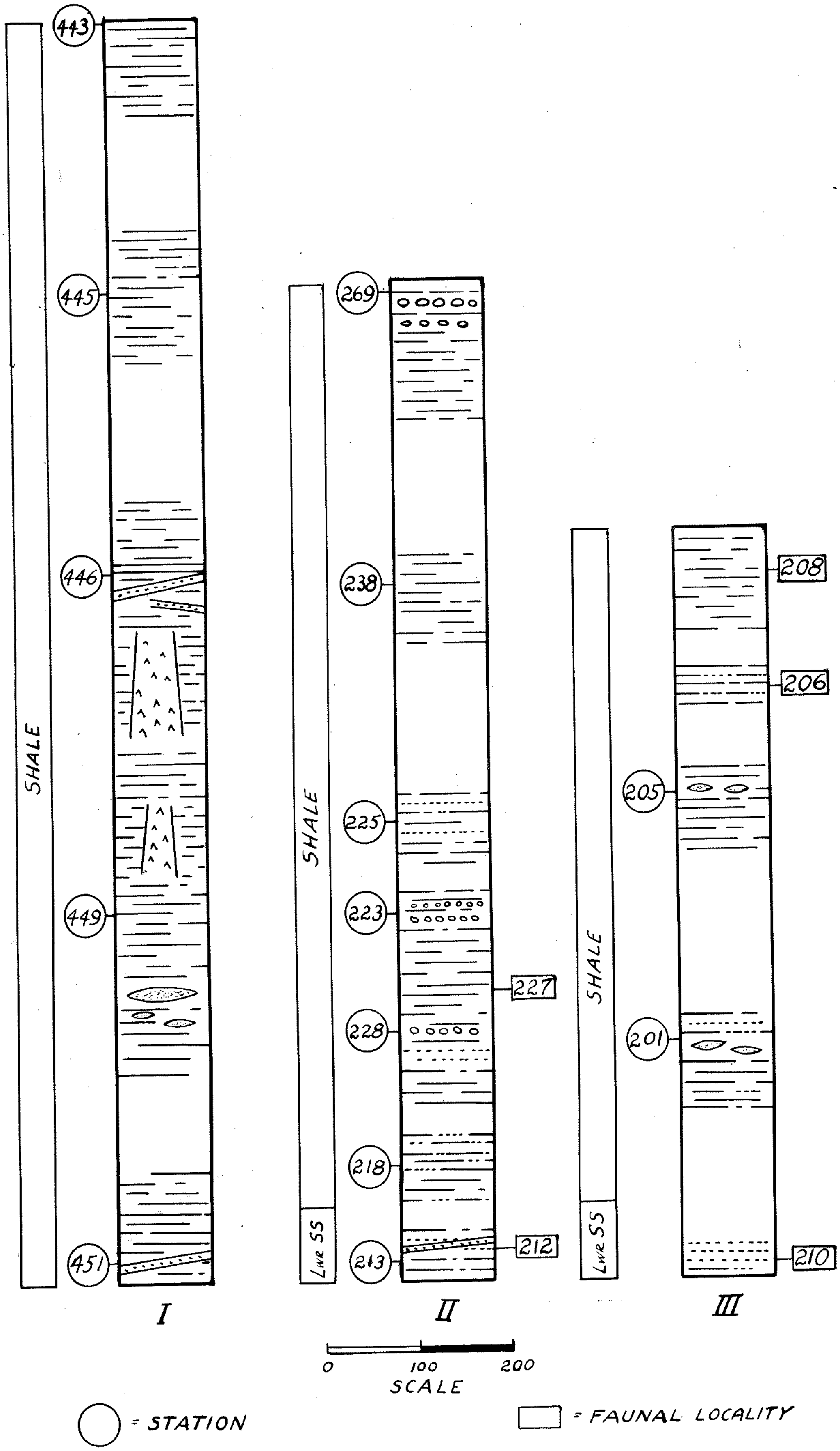
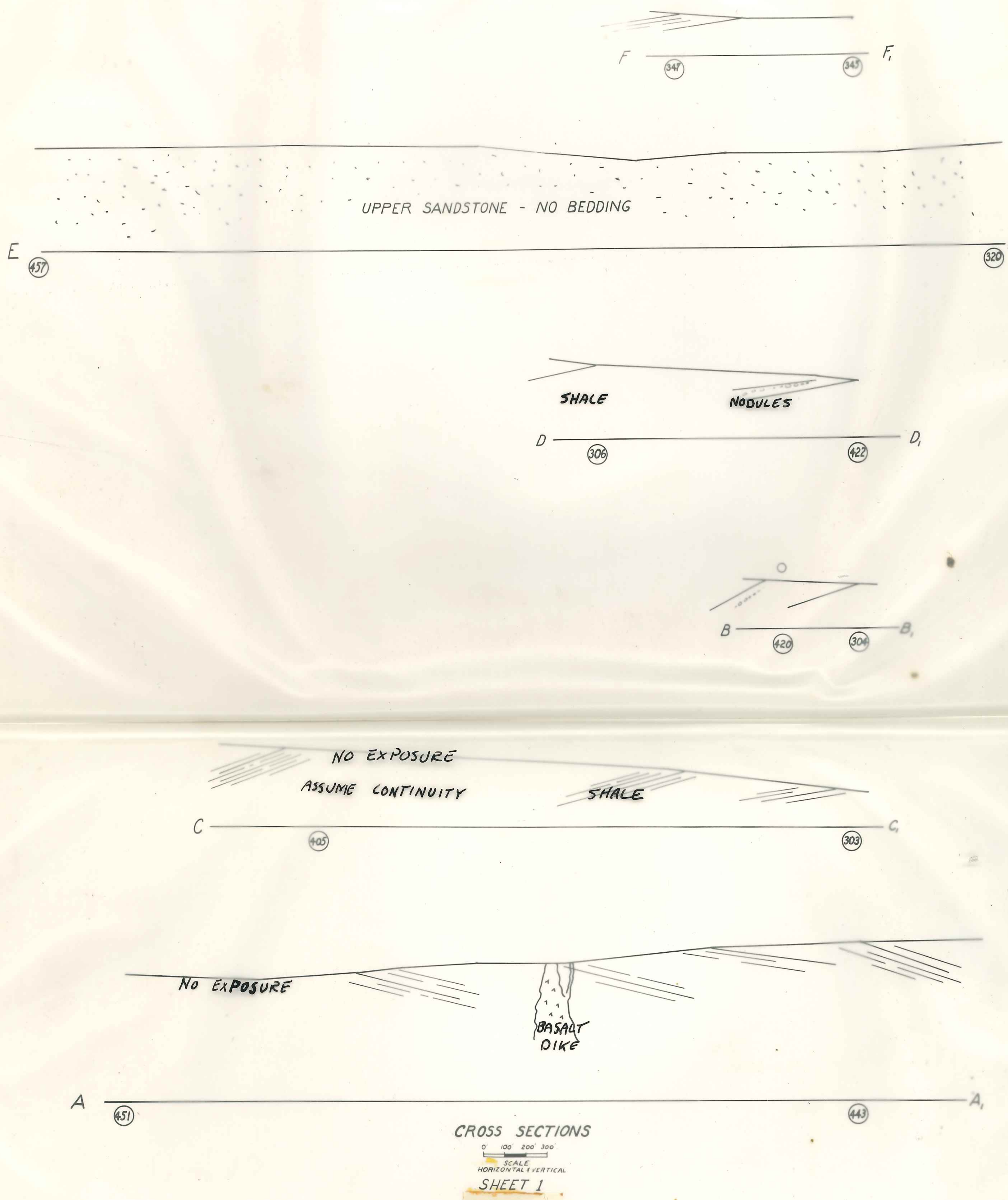


PLATE X



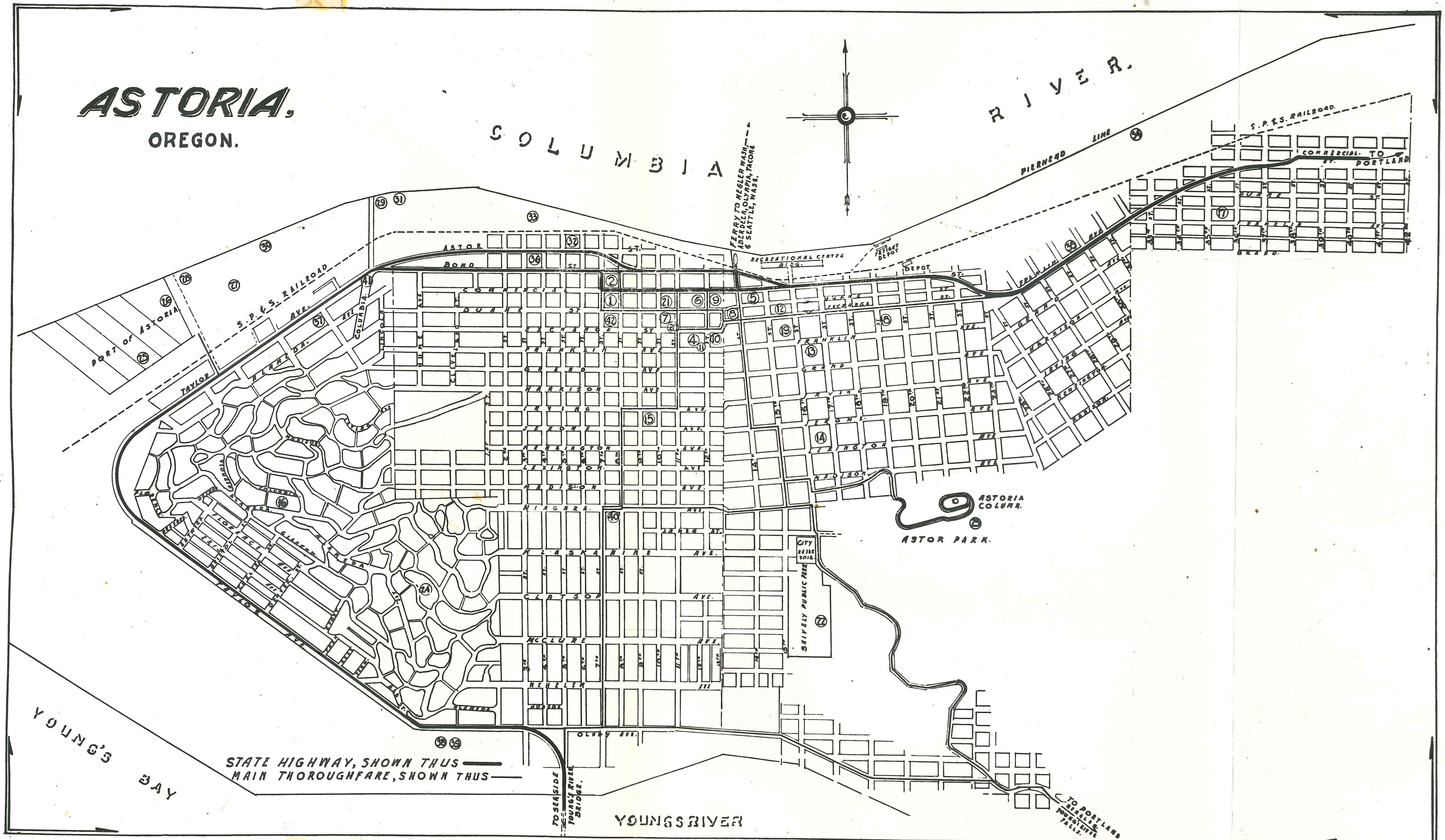
CROSS SECTIONS

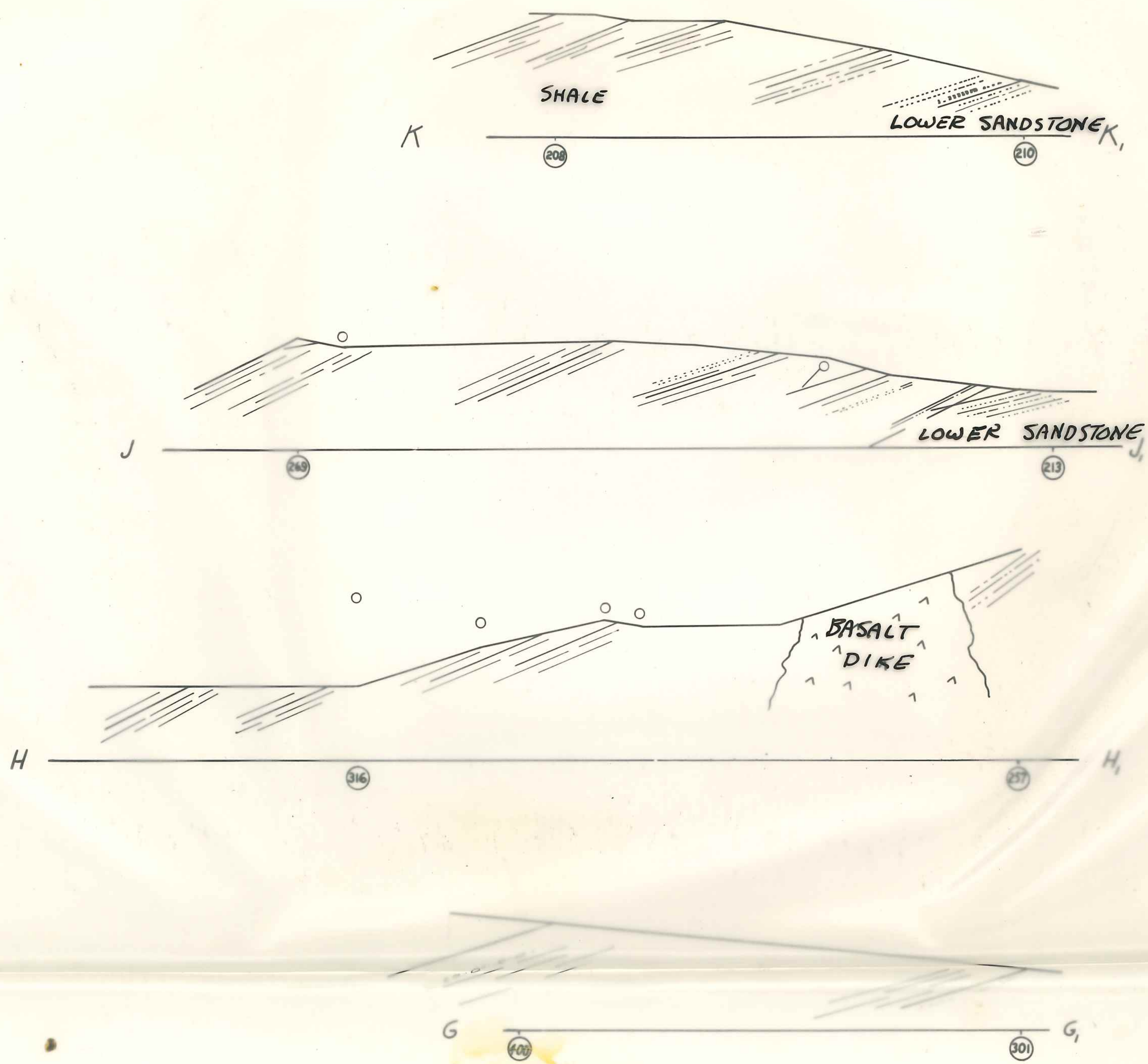
0' 100' 200' 300'
SCALE
HORIZONTAL & VERTICAL

SHEET 1

PLATE XI

3


ASTORIA,
OREGON.
COLUMBIA RIVER.
YOUNG'S BAY
YOUNGS RIVER
ASTOR PARK.
ASTORIA COLUMN.
S.P.&S. RAILROAD
PIERHEAD LINE
PORT OF ASTORIA
FERRY TO MEGLER WASH. ABERDEEN, OLYMPIA, TACOMA & SEATTLE, WASH.
RECREATIONAL CENTER BLDG.
FREIGHT DEPOT
DEPOT
CITY RESERVOIR
SHIVELY PUBLIC PARK
COMMERCIAL ST. TO PORTLAND
TO SEASIDE
YOUNG'S RIVER BRIDGE.
TO PORTLAND
STATE HIGHWAY, SHOWN THUS
MAIN THOROUGHFARE, SHOWN THUS



SHEET 2

PLATE XII

SANDSTONE DIKES

Large numbers of sandstone dikes constitute an unusual feature in the geology of this area. These dike swarms penetrate the lower sandstone and shale over the whole area and are strikingly apparent in forty of the exposures studied in this investigation.

Road cuts in the Columbia River Highway between the Astoria business district and the east side of the Tongue Point Navy base expose many of these dikes as they transect the shale and other dikes. A typical exposure of these is reproduced in Plate VIII. As can be seen in the photograph, dips of the dikes range from 0 to 90 degrees. Many dikes taper out or stop abruptly at the upper end. A majority of the larger shale exposures in the area exhibit this penetration by the dikes.

Medium to coarse grained, grey, micaceous sandstone uniformly comprises the lithology of the dikes. Occasional fragments of shale are imbedded in the dikes at random, lacking any noticeable orientation. The sandstone, though firm and hard, weathers readily so that at the surface it usually can be crumbled in the hand. However, its ability to resist weathering is relatively far greater than that of the shale so that in an exposure of shale the dikes stand out in wall-like relief.

The dikes range in thickness from less than an inch to five feet and over. The larger ones usually are steeply inclined to vertical while ones less than a foot thick typically transect the beds obliquely and occasionally parallel the bed. The latter type dikes never appear completely concordant with the shale but thread through the adjacent beds in a sinous manner. On the west side of 11th Street just south of Franklin Avenue, this type of dike is exposed in the alternating bed of sandstone and shale of the lower sandstone. Although the strength of the sandstone is far greater than that of the shale, a one inch thick sandstone dike courses through both types of rock without deflection at the contacts and with apparent equal ease. A photograph of this exposure may be seen on Plate VII. This particular dike deforms by pressure of intrusion the enclosing beds.

On the south side of the first curve in Alameda Avenue as one proceeds west is an exposure disclosing two parallel steeply inclined dikes. Joining the two dikes and forming an "H" pattern is a this horizontal sandstone sill. This is clearly not a product of fissure filling from above.

On the northeast corner of the intersection of highway 202 and the road leading into Astoria past the city dump is a bank 50 feet high. Exposures on this bank both to the west and to the south effect a cut-away three dimensional sectional view of the strata. The beds of shale in this exposure have a strike of N20°E and a dip of 12 degrees southeast. Transecting the beds are several sandstone dikes the largest of which has an east-west strike and a dip of possibly 30 degrees to the north. Plate XIII shows the west face of this cut and Plate XIV shows the south face. The larger dike seen in these photographs transects the shale at a low angle. To the left of the telephone pole it can be seen to enclose a block of shale.

Originally these dikes were thought to be formed by the filling of fissures from an overlying sand bed. In the first exposures where the dikes could be seen penetrating the lower shale and the lower sandstone could be observed overlying the shale, it was natural to assume this view especially because the first description of clastic dikes had been

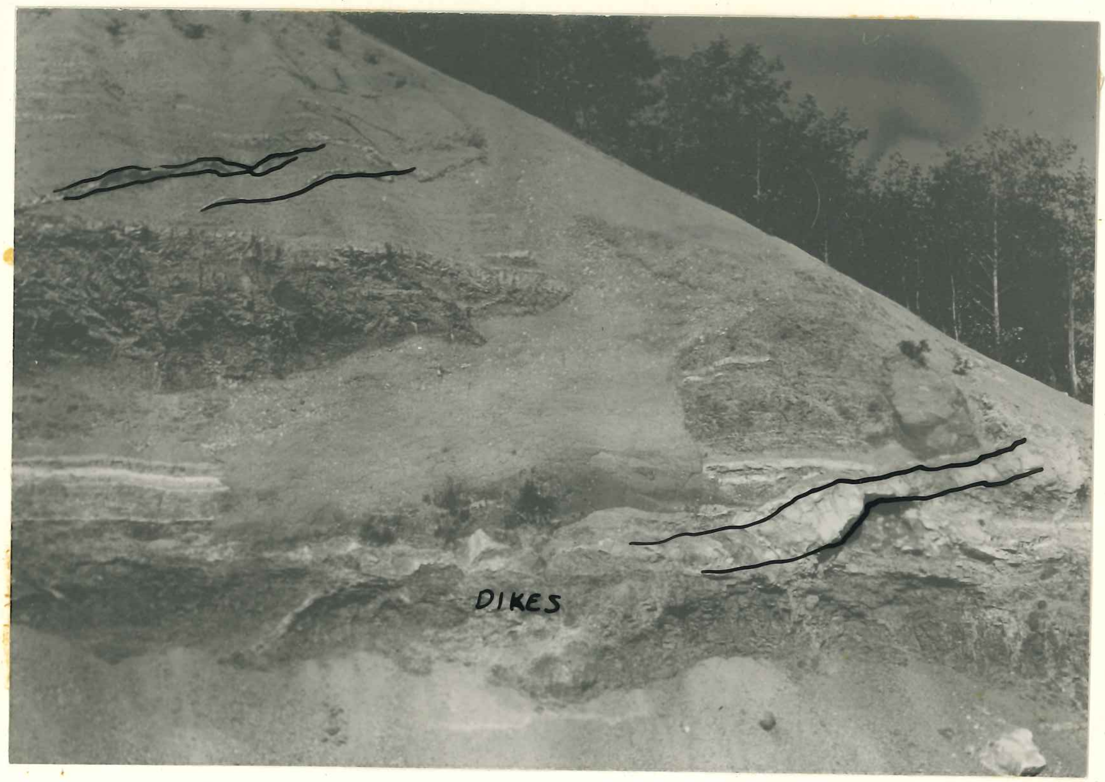


PLATE XIII

Exposure of sandstone dikes. View to the east of west side of bank at the intersection of highway 202 and Astoria city dump road.

PLATE XIV

Exposure of sandstone dikes. View to the north of south side of bank shown on Plate XIII.

published in only 1821 (Newsom, 1903, p. 254) and an origin of injection from below was not proposed until 1872 (Newsom, 1903, p. 259). In regard to the dikes, Dana (1849, p. 654) said:

> "These pseudo-dikes of sandstone were probably formed after or during the deposition of the sandstone, while the region was yet under water. Fissures were opened, perhaps by the same cause that ejected the basalt of the intersecting dikes, and the fissures were filled at once by the granitic sands, along with an occasional fragment of shale from the walls of the fissure. Their number and irregularity evince that these regions have been often shaken by subterranean forces."

From the descriptions given in the preceding paragraphs it should be apparent that a process of fissure filling from overlying sand would not explain the low angle dips and other remarkable features so common in these dikes. The earlier geologists however lacked not only a precedent for considering other than filling as a source of clastic dikes but also lacked the exposures which exhibit the diagnostic criteria.

J. S. Diller (1890, pp. 425-435) published the results of a study of sandstone dikes in Tehama County, California in which he concluded that the dikes were definitely of injection origin. The parallel between his description of the California dikes and the appearance of the Astoria dikes warrants recording several excerpts from this paper:

> "The dike rocks frequently contain fragments of shale. They are generally small, but occasionally as large as a hand and rarely larger. The shale fragments are usually flat and arranged with the scales of mica parallel to the sides of the dike, but this is not always so, for they may be thick, angular, and without orderly arrangement."

Further on he adds:

> "A number of dikes fail to reach the surface, and others are offset in such a manner that it would seem impossible to fill the fissures from above. These facts strongly support those already adduced, and render it certain that the sand was forced up from below to fill the fissures."

In regard to the mechanism necessary to produce this, he says:

> "It appears that if by any means a fissure were suddenly formed from the surface down to the sand saturated with water the latter would rise in the fissure and, if the hydrostatic pressure were sufficiently great, the water would rush forth, carrying the sand with it to fill the fissure and, like an artesian well, overflow upon the surface."

In support of this he quotes Sir Charles Lyell's report referring to the earthquakes of New Madrid, Missouri in 1811-1813:

> "It is said that during the earthquake, powerful jets of water filled with sand and coaly matter issued from these fissures, and distinct traces of them could be seen after the lapse of thirty-four years."

In a later paper Diller (1897, p. 469) noted the close resemblance between the clastic dikes of Tehama County, California and of Astoria. He also noted that Dana had made a mistake in determining the sequence of deposition at Astoria upon the assumption that the dikes were filled from a sand bed above.

Washburne (1914, pp. 17-18) stated evidence for injection origin of the Astoria sandstone dikes in his reconnaissance paper as follows:

> "Sandstone dikes are very abundant. Probably not less than a hundred may be seen in Astoria, and if similar exposures could be had probably as many would appear in the surrounding country, where a number have been found. *** Minor features of structure suggest that the dikes were filled from below when the sand was more or less plastic and mixed with much water. The great abundance of mica suggests that the sand came from the heavy sandstone at the top of the underlying Eocene strata .... The abrupt upward termination of some dikes is an especially potent argument for their deep origin, and the fact that little apophyses and stringers of the sand were forced for many feet through joint fissures one-half inch or less in width indicates that the sand was injected under high pressure."

From all the evidence, both personally observed and also stated by others, acceptance of injection as the mode of origin of the clastic dikes is warranted in this paper.

The answer as to where the source beds of sandstone for the dikes occur is not to be found in this area, but probably is on the north side of the Columbia River where beds of Oligocene sandstone thousands of feet thick are exposed below the Astoria formation. Personal observation in the course of this study could not be made of these beds where they occur immediately below the Astoria formation. However, Dana (1849, p. 652) noted a strong similarity between the dikes and the sandstone on the north side of the river:

> "Half a mile above Astoria a sandstone dike five feet wide intersects the bluff from top to bottom, and may be traced following an east by south course across the flat shores to the edge of the river. The rock resembles a half decomposed granite, and seemed at first to be an instance of granite intersecting Tertiary shale. But further examination proved it to be identical with the granitic sandstone of the opposite shores of the Columbia. Large fragments and chips of the adjoining argillaceous beds are imbedded in the sandstone of the dike."

Later Dall (Dall & Harris, 1892, p. 224) made a similar observation:

> "Dana regards the sandstones as more recent than the shales, a view which is strengthened by the fact that fissures in the shales are still filled with sand resembling that of which the sandstones are composed."

The sandstones to which Dall alludes are the ones exposed on the north side of the Columbia. Both men thought that this sandstone overlay the shale and in the light of their conception of the fissure filling origin of the clastic dikes they considered this identity in sandstone as evidence of this stratigraphic sequence. It appears that their reasoning is valid and the only error involved is the direction from which the dikes were intruded. Therefore it is suggested that the Oligocene sandstone exposed on the north side of the Columbia River is the source for the sandstone dikes exposed in the Astoria area.

ORIGIN OF THE UPPER SANDSTONE

As has been mentioned before, the upper sandstone is noteably lacking in bedding. In the upper part of the sandstone quarry east of John Day Point several beds of shale up to ten feet thick give the only suggestion of bedding of the sandstone in the area. Study of these beds reveals however that fragments and blocks of the shale are to be found scattered through the sandstone below the shale beds. This indicates that no normal sequence of deposition is displayed here and that the apparent strike and dip of the shale beds cannot be extrapolated to apply to the sandstone.

Lack of bedding renders the attempt to determine the thickness of the sandstone bed by stratigraphic methods impossible. Furthermore data from a number of exposures indicate a wide variation in thickness for the bed. The fact that it constitutes the surface bed wherever it occurs and has been subjected to erosion can hardly account for the extreme variations in thickness between different exposures.

Completely lacking are any sandstone dikes which transect the upper sandstone. This could be accounted for by the fact that the upper sandstone was deposited after the dikes had penetrated the shale. If so, then Howe's placing it as the upper member of the Astoria formation which was deposited in normal sequence of deposition is not correct. This could also be accounted for by proposing that fissures in the shale were filled from this overlying bed of sand. However, proof that the dikes are of injection origin from beds below the shale is sufficient to invalidate this hypothesis. One valid possibility left is that the dikes provided the sand for the upper sandstone. Such a possibility might be inferred from the relationship between the shale and the sandstone at their contact. As mentioned before, there is no definite contact but rather a transition to alternating beds of sandstone and shale. These are not beds which could be produced in a normal sequence of deposition.

In a bluff along Highway 202 one-half mile south of the first turn to the south that the highway makes out of Astoria is an excellent exposure of these alternating beds. The lowest bed exposed is sandstone and it is at least eight feet thick. Above this in sequence are six feet of shale, four feet of sandstone, four feet of shale, five feet of sandstone, five feet of shale, and twenty feet of sandstone which form the surface bed. The shale beds vary erratically in thickness and are penetrated in a great many places by apophyses of sand extending from the sandstone members. The bedding in the shale does not follow the irregular border of the shale bed but continues uniformly parallel to the dip of the bed so that it is entirely discontinuous along the contact with the sandstone where it is truncated in erratic fashion by the sandstone. The second sandstone bed from the bottom ranges in thickness from ten inches to four feet as an indication of the irregularity of the beds. Plate XV is a photograph of this exposure.

Across the highway to the west of the exposure described above is an outcrop of massive sandstone which contains an embedded block of shale. See Plate XVI. Extending for several feet from this block and preserving the bedding of the shale is a thin bed of the same shale. Any voilent means of emplacement such as rolling down a slope of this shale in the sandstone is out of the question. A possibility is that water charged sand welling up through fissures could transport and emplace a delicate fragment such as this without shattering it.

In the railroad cut at John Day Point, a four by twelve feet block

PLATE XV

Sandstone sills grading into upper sandstone. View to the east of cut along west side of Highway 202 near the Youngs River. This is station 347 on Plate XXIV.

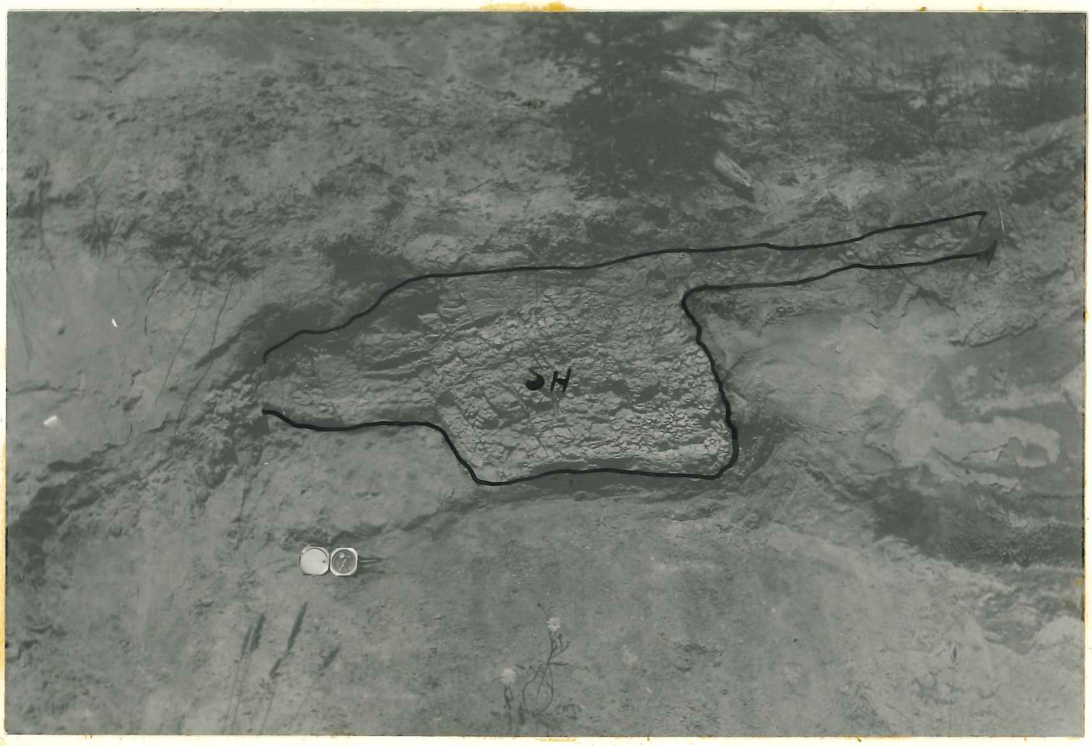


PLATE XVI

Shale block in the sandstone. View taken to the west from 300 yards northwest of station 347. Note thin extension of shale from upper right hand corner of shale block.

of shale is isolated in the massive sandstone. Although this block is of less delicate nature than in the previous case cited, it still could be transported intact only by gentle means. Again transportation and emplacement by welling, water charged sand is suggested. See Plate XVII.

Many more occurrences of the above mentioned phenomena could be given but this is unnecessary as the cases cited are typical.

Revealing evidence has been obtained, however, in a comparative analysis of the sand grains composing the sandstone dikes and the upper sandstone. See Plate XVIII. The grain size percentages show remarkable similarity between the two and indicate that in all probability both came from the same source. It also allows the possibility that one was the source of the other.

All sandstone samples contained nearly identical proportions of quartz, zircon, muscovite, biotite, and opaques.

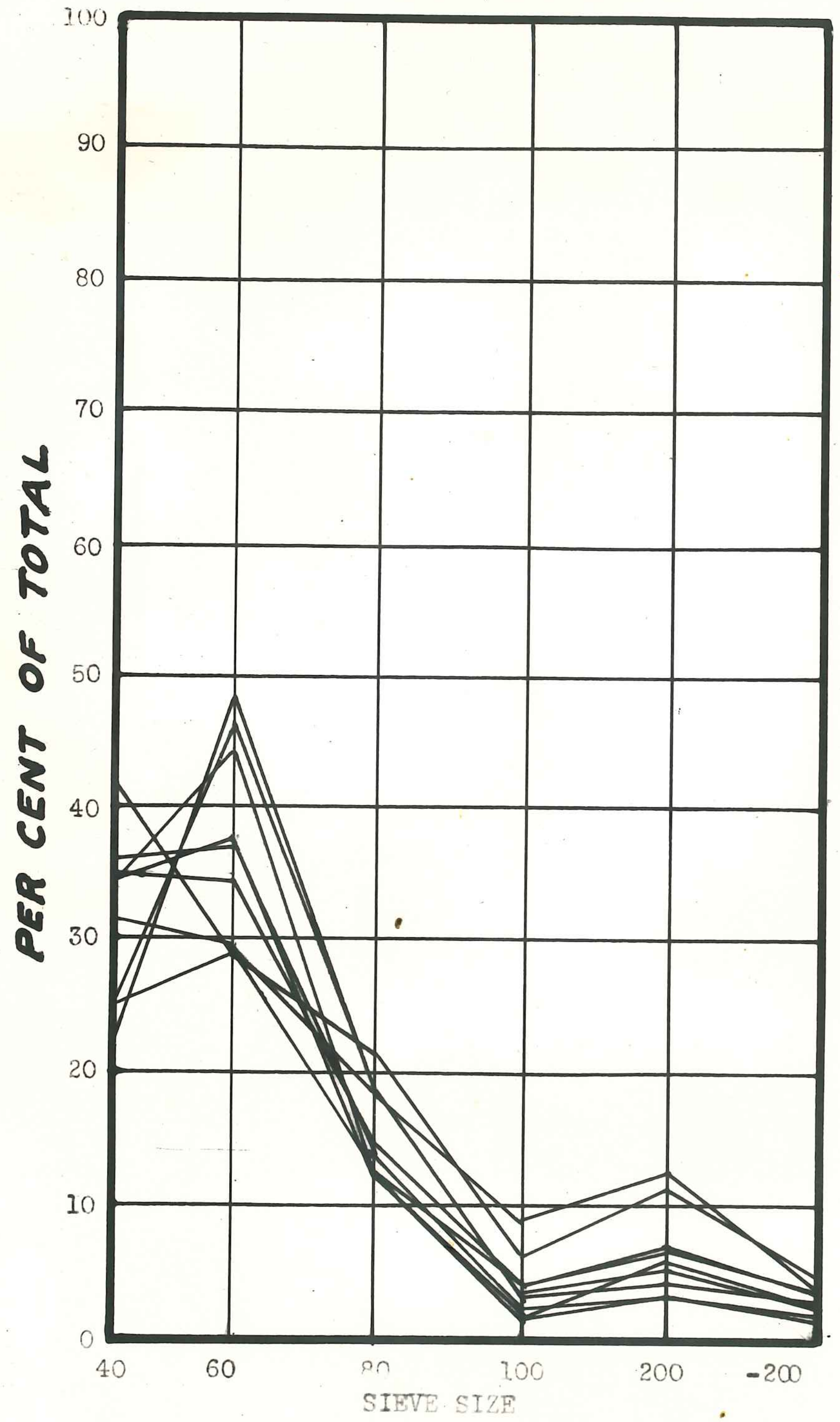
In summary it is suggested that an origin of the upper sandstone in the overflowing on the surface of water-charged sand from fissures now occupied by clastic dikes be regarded as a possibility. If so, the upper sandstone cannot be considered as a member of the Astoria formation since its time relation to the shale is indeterminable.

PLATE XVII

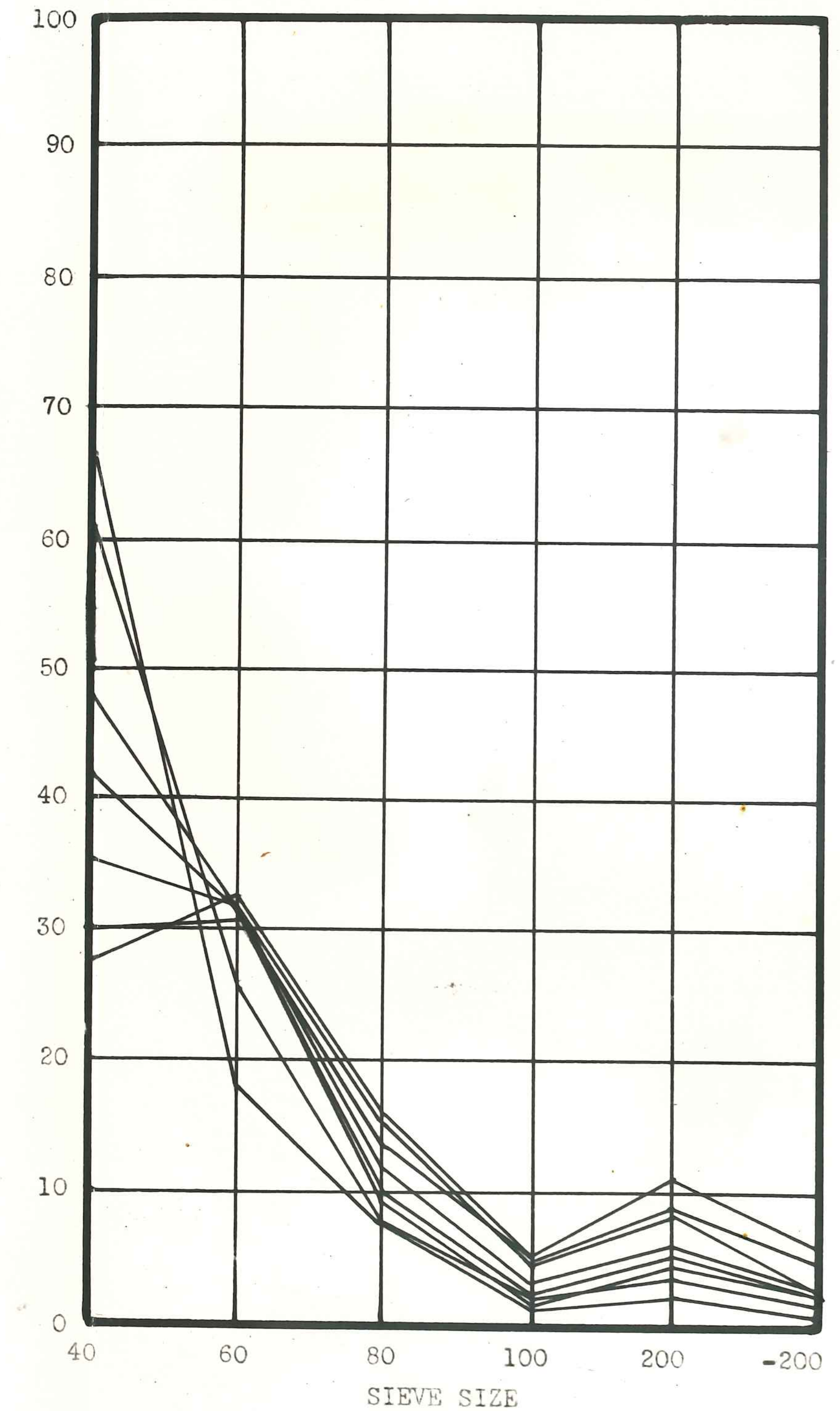
Shale block in sandstone on north side

of railroad cut on John Day Point.

MECHANICAL ANALYSIS



UPPER SANDSTONE



SANDSTONE DIKES

PALEONTOLOGY

MEGAFAUNA

The strata exposed at Astoria gained geological importance because of the extensive faunal collections obtained from them by Dana, Condon, Dall, Diller, and other geologists. The most fossiliferous beds are now concealed although small concentrations of fauna occur in a few of the present exposures. The most common fauna (Hertlein & Crickmay, 1925, p. 260) which have been collected in the Astoria area are listed below. Those marked with an asterisk were found in the course of this study by the writer.

Arca devincta Conrad
Diplodonta parilis Conrad
Macoma arctata Conrad
Marcia angustifrons (Conrad) *
Modiolus rectus Conrad
Nucula (*Acila*) *conradi* Meek
Nucula (*Acila*) *gettysburgensis* Reagan
Panope generosa Gould
Palliolum (*Delectopecten*) *peckhami* (Gabb) *
Pecten (*Patinopecten*) *propatulus* Conrad *
Pecten stanfordensis Arnold
Phacoides acutilineatus Conrad
Solen curtus Conrad
Spisula albaria Conrad
Tellina oregonensis Conrad
Thracia trapezoides Conrad *
Thyasira bisecta Conrad
Venericardia subtenta Conrad *
Venus ensifera Dall
Yoldia impressa Conrad

Bruclarkia oregonensis (Conrad) *
Argobuccinum dilleri And. & Mar.
Bathytoma condonana And. & Mar.
Cancellaria oregonensis Conrad
Calyptraea inornata Gabb
Crepidula praerupta Conrad
Drillia temblorensis And. & Mar.
Galeodea apta Tegland
Ficus modestus (Conrad)
Miopleiona indurata Conrad
Nassarius andersoni (Weaver)

Natica reclusiana Petit
Trophon kernensis Anderson
Trophosycon kernianum Cooper
Turris medialis Conrad
Turritella oregonensis Conrad

Aturia angustata Conrad

Dentalium conradi Dall

Terebratalia obsoleta Dall
Terebratulina unguicula Carp.

In addition to this list of the most common fauna, the Brachiopod Hemithyris astoriana Dall was obtained during this study in large quantities from one zone in the lower sandstone.

The following faunas have been collected from the localities listed below:

Faunal locality 216.

Pecten (Patinopecten) propatulus (Conrad) Plate XIX
Thracia trapezoidea (Conrad)
Marcia angustifrons (Conrad)
Venercardia subtenta Conrad

Faunal locality 227.

Palliolum (Delectopecten) peckhami (Gabb)
Sponge casts
Carbonized wood
Seed Pod (?)

Faunal locality 228.

Palliolum (Delectopecten) peckhami (Gabb)
Sponge casts
Leaves from deciduous plant

Faunal locality 210.

Bruclarkia oregonensis Conrad
Pecten (Patinopecten) propatulus (Conrad)

PLATE XIX

Pecten (*Patinopecten*) *propalutus* (Conrad)

Faunal locality 212. (See Plate VII)

Palliolum (Delectopecten) peckhami Gabb
Hemithyris astoriana Dall

Faunal locality 202. (See Plate VI)

Palliolum (Delectopecten) peckhami Gabb

Faunal locality 410.

Hemithyris astoriana Dall

Howe (1922) observes that 43% of the fauna of the Astoria type section are present in Miocene formations in California and that it has a close relationship to faunas of Asia. The fact that both groups are present indicates that this area during the Miocene was intermediate between the warmer southern waters and the colder northern waters.

MICROFAUNA

Foraminifera are abundant in a few zones in the shale. Dr. R. E. Stewart (1947) has recently completed a study of them and reports many new species. However, his paper has not yet been published. A few of the more prominent genera collected at the following localities have been determined provisionally.

Faunal locality 210.

Cyclammina sp.

Faunal locality 223.

Cyclammina sp.

Faunal locality 226.

Bolivina sp.
Robulus sp.

Faunal locality 227.

> *Robulus* sp., similar to *Robulus smileyi* Kleinpell
> *Bulimina* sp.
> *Siphogenerina* sp.
> *Uvigerina* sp.

Faunal locality 439.

> *Pseudoglandulina* sp.
> *Siphogenerina* sp.

The faunal localities in Astoria are here listed:

202 Fifty feet west of 7th and Exchange Streets.

210 Fifty feet west of 5th and Commercial Streets.

212 The west side of 11th Street 50 feet south of Franklin Street.

216 The southeast corner of 12th and Franklin Streets.

223 The south side of Grand Street 30 feet west of 9th Street.

226 The west side of 9th Street 100 feet south of Grand Street.

227 The north side of Harrison Street from 9th to 10th Streets.

228 The west side of 10th Street 75 feet north of Harrison Street.

410 The southeast corner of 34th and Franklin Streets.

439 On north side of highway U. S. 30 0.1 mile east of Fernhill road.

GEOLOGICAL HISTORY

The Astoria area during Miocene time formed a shallow embayment of the sea. Evidence for this is a fauna consisting of genera whose habitat is that of shallow water, and glauconitic greensand which is now regarded as forming most readily in shallow bays (Takahashi, 1938, p. 503-512). The close proximity of the shore is indicated by the coarse grain size in the sandstone, by the multiple alternations of sandstone indicating fluctuating conditions of deposition, and by the presence of leaves and carbonized wood occurring extensively in concretions.

At an undetermined time following the consolidation of sandstone and shale, these rocks were fissured by disturbances and water-charged sand from an underlying bed was injected into and through these beds. Possibly a quantity of sand great enough to flow out on the surface was ejected where it formed an irregular sand deposit on the shale.

Following the sand injection, basalt intruded all the beds present and in localized areas deformed the strata.

The amount of warping and faulting indicate the activity to which the area has been subjected.

Mid Miocene strata on the north Pacific Coast are characterized by shallow marine deposits which do not extend far inland except in the embayments in Washington. Eastward mid-Miocene lava beds become thicker. East of Portland lava flows comprise almost all the Astoria formation and are known as the Yakima basalt.

IGNEOUS INTRUSIVES

Aligned roughly in a chain along the crest of the central crescent shaped hill are sporadic outcrops of basalt. This basalt is the only strong and weather resistant rock in the area and as a result it is extensively quarried for use as building material. Four of these quarries located on the sides of Coxcomb Hill furnish excellent exposures of both the basalt and of the contact between the basalt and the shale. The largest exposure of all is on Tongue Point, a spit composed of basalt.

Curiously enough, with the exception of the north end of Tongue Point where the river is actively cutting, there is no natural outcrop of basalt in the area despite the fact that its resistance to erosion provides the support for the central hill. One would expect to find it standing above the shale in high outcrops but at the surface it seems to break up and mix as fragments with the clay mantle. Every exposure was made by some excavation of man.

Small dikes of basalt can be seen in many excavations near the axis of this central ridge. In the large basalt quarry on the north side of Coxcomb Hill, a large basalt dike splits into smaller dikes as it continues upwards and terminates in a feathered-out pattern. In the quarry adjacent to the south side of the Astor Column road, a single large dike is exposed. At the base of the exposure it is several hundred feel thick but it tapers to less than one hundred feet thick at the top of the exposure. The beds of shale near the contact with this dike display intense deformation.

In contrast to this deformed contact is the contact exposed on the cliff on the west side of the city dump where lines of bedding maintain a uniform dip even though invaded and transected by a large basalt mass. See Plate XX.

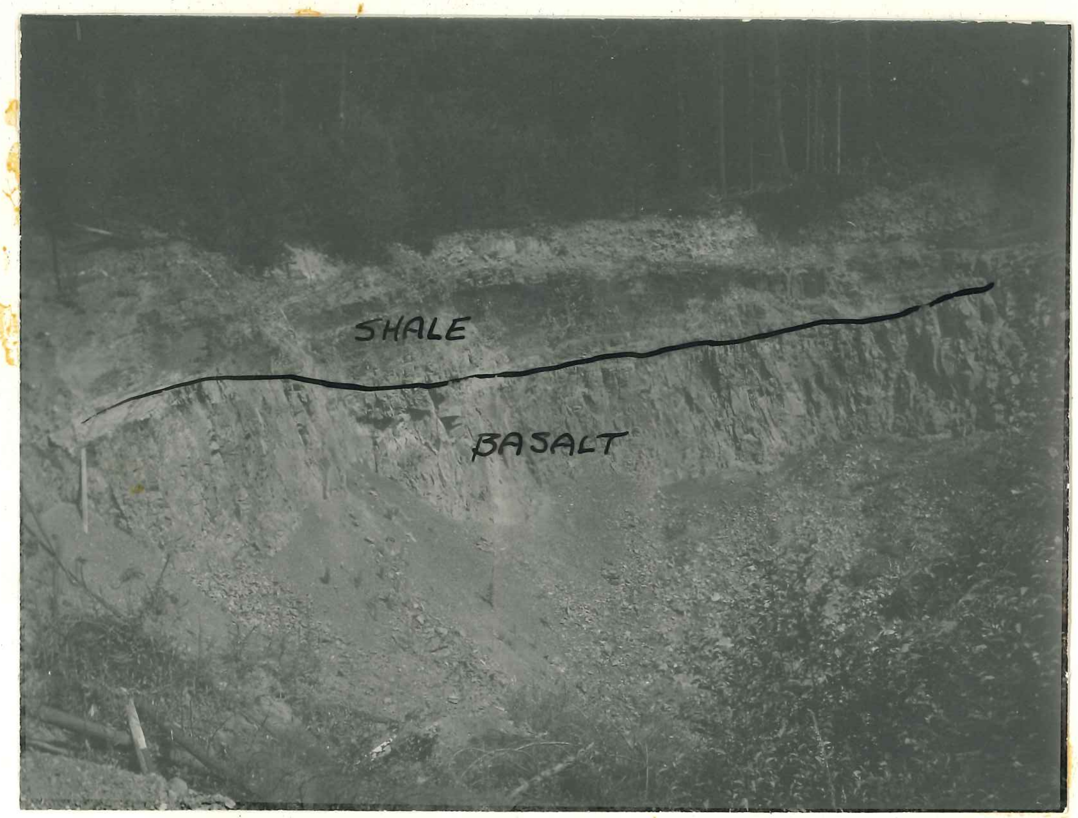


PLATE XX

Exposure of shale-basalt contact in bluff on west side of the Astoria city dump.

PLATE XXI

Photomicrograph of basalt thin section. Sample taken at the basalt-shale contact. Groundmass of glass is predominant.

20 X Crossed nicols

PLATE XXII

Photomicrograph of basalt thin section. Sample taken two feet from basalt-shale contact. Note increased amount of plagioclase apparent in comparison with sample taken at contact.

20 X Crossed nicols

STRUCTURE

The geologists who have studied the rocks at Astoria have had different exposures as sources of data. New excavations were made from time to time and old exposures were covered over. This explains to a certain degree the disagreement in the different reports concerning the structure. At the localities where exposures were available for observation, the different reports are in agreement.

Washburne (1914, p. 1-108) in 1913 was the first to measure the strata at this locality. By plotting strikes and dips taken from the strata on the north side only of the central hill he obtained southwest dips west of 35th Street and southeast dips east of this line. This led him to conclude that the axis of an anticline lay in the vicinity of 35th Street and that it plunged southward. On this basis, he suggested that if in spite of all negative indications anyone wished to drill for oil in the area, this supposed 35th Street anticlinal axis would be the logical location.

In 1920-1921, Howe (1922) made a more detailed study of this structure including not only Washburne's area but also the ones south of the hill and south of Youngs Bay. More exposures were available for him resulting in the ascertaining of more geologic details. Howe concluded that contrary to Washburne, the main structure was that of a syncline whole axis lay south of the city, possibly extending through the south side of Smith Point and across the John Day River. He suggested it was sinous in character and plunged gently to the northeast. From this standpoint, all the strata exposed on the north side of the central hill comprised part of the north limb of the syncline. Indication of structure in the south limb was derived from six exposures with north dips on the south side of the main hill and in beds exposed along the Lewis and Clark River road.

The data obtained in the course of this study substantiate Howe's conclusions regarding the structure. In the shale exposures along the highway several hundred yards south of the west end of Smith Point the beds strike N75°E and dip 31 degrees southeast. Northeast of this location at the intersection of 1st and Exchange Streets the strike has changed to N40°W and the dip to 18 degrees southwest. This attitude gradually changes to the east until at 15th Street and Jerome Avenue the strike is N85°E and the dip 13 degrees south. Continuing eastward the strike changes gradually to northeast-southwest. At 38th Street and Franklin Avenue the strike is N40°E and the dip 22 degrees. This approximate strike and dip continues to the John Day River. These attitudes describe the north limb of a curving syncline.

The south limb of the syncline is indicated at Alameda Avenue and Hanover Street where the strike is N70°W and the dip eight degrees north. Four miles to the east on the Navy pipe line road several exposures indicate an average strike of N70°E and a dip of 10 degrees north. These exposures constitute the evidence for the character of the south limb of the synclince.

The cross sections on Plates XI and XII depict graphically the above data.

A local regional structure consisting principally of syncline is indicated by the field evidence. The axis of this syncline lies somewhere immediately south of the crest of the main hill ridge where it follows a rather sinous course from Smith Point to the vicinity of the mouth of the John Day River as shown on Plate XXIV.

SUMMARY

The stratigraphic section of the Astoria formation at the type locality is composed from the base upward of lower shale, lower sandstone, upper shale, and upper sandstone.

Knowledge of the lower shale must be inferred from reports of earlier investigators as this bed is now entirely concealed. Since these reports do not agree as to the age of this shale, it is not possible to determine if this belongs to the Astoria formation. It may be of upper Oligocene age.

The lower sandstone is the lowest exposed member of the Astoria formation. It has a minimum thickness of 110 feet and is composed of alternating thin layers of sandstone and shale. It contains in its fauna _Hemithyris astoriana_ Dall, _Palliolum (Delectopecten) peckhami_ (Gabb), _Pecten (Patinopecten) propatulus_ (Conrad), and _Bruclarkia oregonensis_ (Conrad).

The upper shale overlies the lower sandstone. It is composed of arenaceous and argillaceous shale and contains concrections, greensand beds, and cherty nodules. In the western part of the area it has a minimum thickness of 1,100 feet and in the eastern part a minimum of 1,400 feet. Its fauna includes _Thracia trapezoidea_ Conrad, _Marcia angustifrons_ (Conrad), _Venercardia subtenta_ (Conrad), _Pecten (Patinopecten) propatulus_ (Conrad), _Palliolum (Delectopecten) peckhami_ (Gabb), and _Hemithyris astoriana_ Dall. It also contains fossil leaves.

The fauna of the Astoria formation at the type locaility are in close agreement with the fauna of the Astoria formation in other parts of Washington and Oregon. Approximately fifty per cent of the fauna at Astoria are also found in the Temblor formation of California.

The upper sandstone overlies the upper shale. It is composed of coarse grained micaceous sandstone and contains fragments of shale but no fossils.

Its thickness is undetermined. A possibility exists that it was formed from surface outpourings of sand dikes.

Many sandstone dikes transect the lower sandstone and the shale but do not transect the upper sandstone. Evidence strongly indicates an origin of injection from underlying water-charged sand beds. Field relationships place the dikes as post lower sandstone and upper shale time, contemporaneous or pre-upper sandstone time, and prebasalt time.

Basalt dikes invade all sedimentary strata in the area and cause considerable deformation. The basalt is composed of bytownite-labradorite plagioclase, augite, and glass.

The strata of this area form an east-west trending syncline, the axis of which is along or near the crest of the central ridge.

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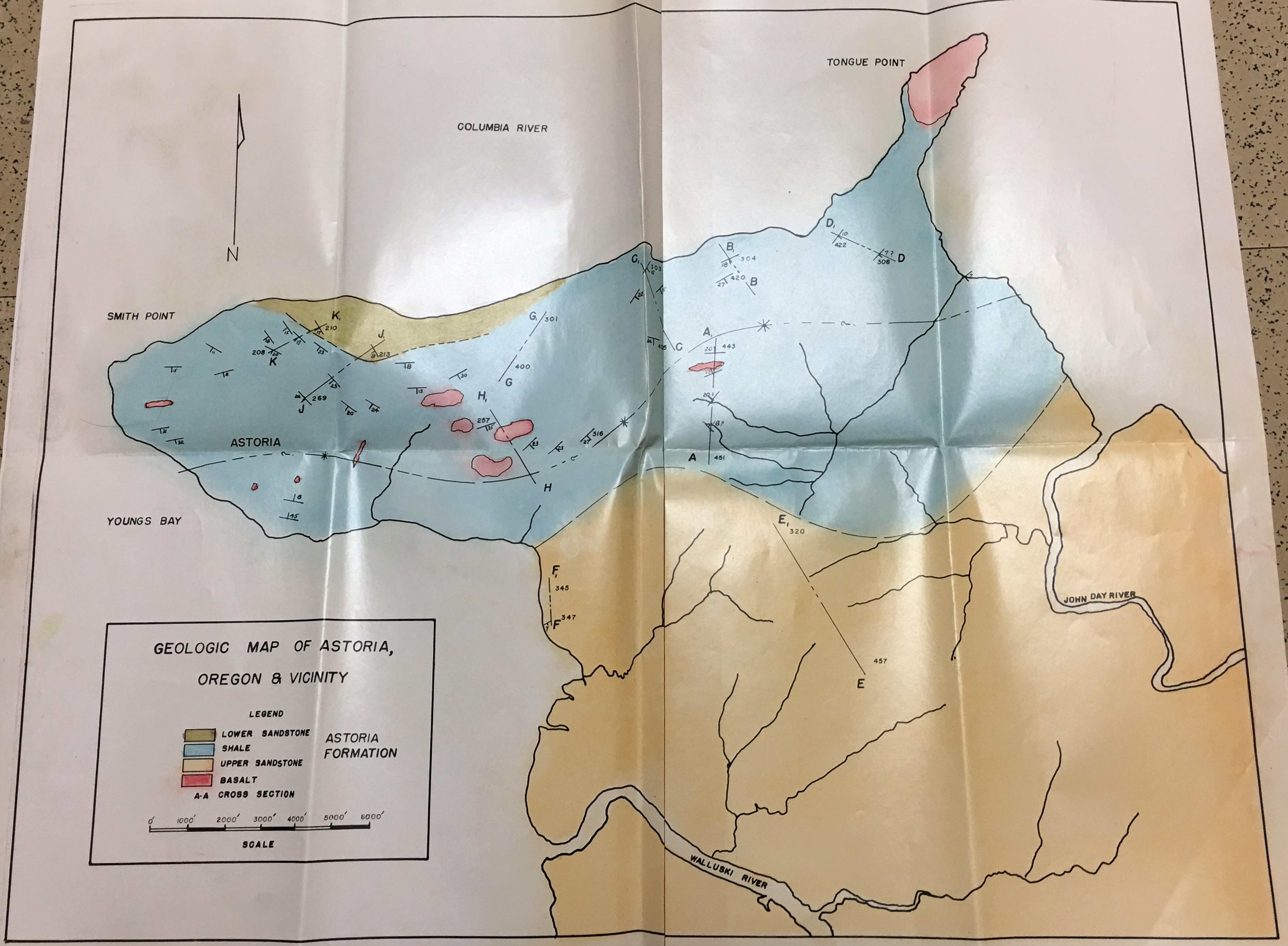
GEOLOGIC MAP OF ASTORIA,
OREGON & VICINITY
LEGEND
LOWER SANDSTONE
SHALE
UPPER SANDSTONE
BASALT
A-A CROSS SECTION
ASTORIA FORMATION
0' 1000' 2000' 3000' 4000' 5000' 6000'
SCALE
N
COLUMBIA RIVER
TONGUE POINT
SMITH POINT
ASTORIA
YOUNGS BAY
JOHN DAY RIVER
WALLUSKI RIVER