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EOLATIVE SOILS OF WASHINGTON WHEAT LANDS

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The rich volcanic soils of the wheat lands of central Washington constitute its chief source of potential wealth. Although robbed of half their natural productivity by the precipitative effects of the lofty Cascade Range the peculiar soils of this tract lead the entire United States in the *per capita* yield of wheat. This region, best known as the Palouse Hills, occupies the eastern part of Washington north of the Snake River and south of the Spokane plains.

Although possessed of very mature topography these Palouse Hills are of relatively recent origin. Successive Mid Tertic lava flows which build up the great Columbia Plateau are separated by residual soils mixed with volcanic ash, and mingled with the clays and sands laid down in marginal lakes. Although so hard the lavas yield readily to weathering influences and their surfaces soon assume the rolling outlines which characterize the Palouse hill-land with its wide, flat-bottomed valleys and concave slopes.

During this early period the climate seems to have been much more moist than it is today, a circumstance due to the fact that the Cascade Mountains are not yet warped into position. During this period, also, erosion lowers greatly the original height of the Plateau. Weathering taking place much faster than stream transportation deposits residual clays 200 feet or more in thickness form. Later in the Tertic period Lake John Day is formed wherein are deposited extensive bodies of sands, clays and gravels brought in from the surrounding hills lying to the west, together with much fine pumice discharged from their volcanic vents.

Towards the close of the Tertic period those same orogenic forces that upwarp the Cascade Mountains cause local warpings

of the plateau just mentioned. The Cascades precipitating most of the moisture on their west flanks thus cause arid climate conditions to prevail on the east side over the plateau, changing the green, grass-covered slopes of summer to brown, barren tracts. Work of the westerly winds become active and begin to pick up the fine materials of the John Day beds and transport them to the Palouse region. There, during the late summer when the vegetation has died these same winds shift the dry soil of the southwest slopes to the leeward side giving the hills a dune structure.

As the general uplift at the beginning of the Quaternic period results in the glaciation in the high lands and on the Spokane Plains, new agencies begin operation. The long rigorous winters kill the vegetation and wind work becomes very active. During the early part of the glaciation the hot, short summers give rise to immense floods of yellow, muddy water which more than fills the existing stream channels, and doubtless back into the side-valleys, where they drop their loads of silt. Bergs of ice floating into these embayments leave many grooved erratics that are found up to within less than a hundred feet of the hilltops. The long cold winters allow the floods to recede, only to be followed by the succeeding floods of the next summer.

As wind work is especially active in the winter months eolian material is also deposited in the flooded valleys on the layers of clay left at the yearly retreat. Since the Snake-Palouse ridge is higher than the country to the north this flooded condition covers the entire region. Washtucna Coulèe through which the pre-glacial Palouse River drained is all too small to carry these floods, and the waters backing up then fill all the valleys until they find a path across the divide to the Snake River. In time the flood waters erode this channel deep enough to change the course of the Palouse River permanently to the south, thereby shortening its length of 100 miles, and produce the beautiful canyon and water-falls of today. With each recurrent summer's flood a new layer of clay is deposited. As the main drainage channels are worn deeper and deeper the waters gradually withdrew from the upper valleys and confined themselves to the main channels of the scab-lands. In the depressions of these old, abandoned river channels are found our rock-walled lakes of today.

The lower hillsides bordering the scablands have much steeper slopes than the interior hills and reveal the soil structure in many places.

The Spokane ice gives us some idea of the time when these loessial deposits are laid down, for we find no trace of wind deposits on these scab-lands. The rocks are mostly bare and only slightly effected by weathering, although talus-slopes form to three-fourths of the height of the canyon walls. The advent of the lesser Wisconsin Ice does little to modify the Palouse Hills, as its waters reverted only to the Grand and Moses coulèes further deepening the stream channels. However, if glaciation and cold leads to an increase of wind-work, the lack of such deposits on the scablands leads us to conclude that wind-work in transporting material from the west central portions of the plateau is indeed a small factor in the soil complex of the Palouse Hills.

The hills about Spangle have erratics to within a hundred feet of their top; and they have dune-shaped formation, with steep northeasternly slopes and more gradual ones in the south, indicating the shifting of the soil by the wind. Wheat is uniformly better on the north slopes and in the wide valleys than on the hilltops or the south slopes, a fact which seems to be due to the wind-shifted soils being richer, than thinner, residual soils of the hilltops and south slopes.

Artificial excavations and well-borings indicate a residual origin of the most of these soils. Many places observed reveal the lava which is reached by the main stream channels to change from the solid rock to angular pieces, then to smaller particles, and finally to the yellow clay-soils covered with the dark humus.

These Washington wheat soils are mainly residual in origin, formed by the decaying of the lava with its interbedded layers of clay, ash, and silt, but they are modified and moved by wind-action and are covered with thin layers of wind-born dust from the Big Bend country and an ash from the western volcanoes. Clays from the flood-waters of the Spokane glaciation are also mingled.

An account of the origin of the Palouse soils is a long history. This history is closely interwoven with that of the country about and particularly with that of the region lying to the west. The geological course of events may be briefly outlined.

At the close of the Cretacic period the present site of the Columbia Lava Plateau was occupied by a number of shallow lakes, or rather arms of the sea with marshy borders extending east into Idaho and South into California. Low-lying hills lined its west ern border that extended some distance beyond the present coastline of the State, and occupied the present site of the Coast and Cascade mountains. To the east were higher hills of crystalline and metamorphic rocks, mainly granites, gneisses, and schists.

On the lake bottoms were deposited thick layers of clays, and sands often aggregating several thousand feet in thickness. Along the marshy borders were interbedded the Kittitas coal measures. Erosion continued until the western highlands were worn to a peneplane.

In this old region orogenic forces started movements of folding and faulting, and large fissures appeared. From the depths of these, where the pressure had been removed, issued floods of lava as thin as water. In all the history of the earth no greater floods of molten rock ever appeared; and only those of Iceland and the Deccan Plateau in India at all compare. The lava flows spread over thousands of square miles of the country, filling up the lakes and the valleys, damming rivers, and covered the land to depths of hundreds of feet. One set of these fissures were in the folds where the present Cascade Mountains were to be built. Others occurred in central Washington, in southern Idaho, and northern California. Another probably extended through Spokane, on the site of the present falls.

In some places violent eruptions occurred and pumice first was poured out far and wide and cinder cones produced. Along the drainage-lines thousands of small craterlets contributed their share of volcanic ash and cinder. Long intervals of quiet occurred. Then weathering produced residual soils. Trees grew and abundant vegetation and animal life existed along the shores of the new lakes in the lava-blocked valleys. Clays, volcanic ash and sands were also deposited on these lake bottoms, as now well exposed in the railroad cuts about Spokane. The embedded fossils give us a record of the life of the period.

Again new floods of lava broke forth in different sections burying all in another deluge of liquid rock. Periods of quiet were followed by succeeding lava floods until as many as twelve layers

were formed in places to the depth of nearly a mile. These are now exposed in the canyons of the Palouse, Snake, and Columbia rivers. Most of the low-lying hills were covered; but a few of the higher ones still projected above the lava surface. Amongst these were the Blue Mountains, Steptoe Butte, Medical Lake Hills, Browns Mountain, and Little Baldy.

Often interbedded with the later lava flows, in the Pasco region especially, are lacustral deposits of volcanic ash, clays, and fine gravels. This was due either to the fact that the Columbia River was unable to cut its channel as fast as the highlands were being warped into position or a subsidence caused a large lake to form extending south into Oregon and reaching as far east as Dayton. This lake existed until deposits to a depth of several hundred feet were formed. This epoch was marked by violent volcanic eruptions in the western high lands, indicated by the fact that deposits of white volcanic ash several feet in thickness were deposited. During the existence of this lake the climate was mild and moist and a semi-tropical flora clothed its shores.The climate was moist since the Cascades were yet unborn. After the lake was drained, or completely filled in by sediments an interval of erosion took place. The lava, although hard, weathered as rapidly as sandstone and thick layers of residual clays were formed. The streams wore down their valleys and the rolling, mature topography of the Palouse Hills was produced. Much of the John Day beds was moved, and the general level of the country was lowered some hundreds of feet.

New mountain making forces began operation at the close of the Tertic and the opening of the Quaternic periods. The John Day beds were uplifted in places and a great fold appeared to form the new Cascade Mountains. The crests of this lofty ridge cut off the supply of moisture from the sea, and the Columbia Plateau soon became a semi-arid region. On the tops and sides of these new mountains volcanic action produced tall cones of lava-cinder and ashes. Thus were upbuilded Mounts Rainier, Hood, Baker, St. Helens and others. Ashes were thrown out from their vents and carried eastward by the prevailing westerly wind and deposited upon the rolling hills and valleys. The Plateau region rose to an average elevation of some 2500 feet. In places on the Plateau developed monoclinal ridges. One pro-

duced the Saddle Mountains; another Rattlesnake Ridge, and farther north appeared the Frenchman Hills and Badger Mountains. Through Rockford, Spangle, Medical Lake, Reardon, Davenport, and on farther west across the head of the Grand Coulèe a low fold appeared shifting the drainage to the south and forming the basin regions. To the north of the Snake River and parallel to it another fold arose shifting the drainage of that region north into the Palouse River, and causing that stream to enter the Snake River near Pasco. As the Cascades were being warped into position the Columbia River cut its deep, narrow gorge, to be widened later by the Glacial floods. East of the Blue Mountains, in Idaho, another fold appeared through which the Snake River cut to the depth of nearly a mile, exposing the alternating layers of lava and clay.

This was a time of general uplift in the region. The elevation, together with astronomical causes, covered the Cascades, the Okanogan Highland and the mountains of Canada to great depths with ice. Great ice-sheets pushed their way westward and southward. One tongue came down and scoured out the basin for Lake Chelan. It then pushed on across the Columbia Valley and joined others coming down the Methow and the Okanogan valleys. The combined glacier dammed the Columbia River and caused its waters to seek a new route, which was through the Grand Coulèe. Other streams of ice followed the Chimakane and the little Spokane valleys, joined fronts, and pushed across the Spokane River, dammed its valley and formed a great lake to the east, Lake Spokane. It advanced south with a frontage at Spangle, Meadow Lake, Reardon, Davenport, and westward. It scoured off the Palouse Hills in its path, forming the Spokane Plains. It rested hard against the Palouse Hills at its front. It dammed Hangman Creek whose waters, together with the Glacial floods, filled the upper valley as far as Rockford, and up California Creek to Mica. These flood-waters were called Lake Latah. Through the Chester Draw came the waters from Lake Spokane.

With the coming of the Glacial Period the winters grew long and cold and the summers short and very hot. As a result most of the vegetation was killed, and wind-work became more active so that much of the fine materials on the hills to the west was picked up and deposited to the eastward. During the hot summers great streams of yellow, muddy water issued from the ice-front and filled the old drainage lines to overflowing, and for a time at least spread over the surrounding country, and, flooding the side-valleys, left it seasoned layers of silt. Great ice bergs must have formed and floated into the embayments of the side-valleys, as erratics are found within a hundred feet of many of the hill-tops. This flooded condition existed as far south as the Snake River since the outlet of the Palouse River through the Washtucna Coulèe was all too small to carry the floods poured into it from the north, and its waters backed up, flooding the country until they broke across the Palouse Ridge and scoured out the Palouse canyon and falls of today, and thus shortening its path some hundred and fifty miles to the Snake River. In time these yellow, seasonal floods removed the Palouse Hills in their paths in strips ten to twenty miles wide, and cut down into the lava beneath leaving many rock-walled channels. In all some twelve outlets were formed from the ice-front extending from Rock Creek on the east to Moses Coulèe. These removed three thousand square miles of the Palouse Hills and formed them into the channeled scablands.

This ice-sheet, known as the Spokane Glacier, finally retreated, as the climate grew warmer. Again, after many years there was another advance of the ice, the Wisconsin Glacier. This did not cross the Spokane and Columbia Rivers, except to the west of the Grand Coulèe. Grand and Moses Coulèes were the only ones of the old channels to be occupied by its flood-waters. Coincident with the last stages of the Wisconsin ice invasion submergence occurred in the west, lowering the Willamette and Quincy and Walla Walla sections, so the land was flooded with the Glacial waters, and thus Willamette Sound and Lake Lewis were formed which filled up the channels and beds with deposits of gravel and silt to the height of nearly 400 feet, nearly all of which was removed from the river channels since.

Suggestion is made that the Glacial floods of the Spokane Ice were of too great volume, as in the minor river channels, to pass through The Dalles, and lower Columbia canyons, and that these flood-waters filled the Willamette valley and the Lake Lewis basin due to back flooding rather than submergence. If the above were true these bodies of water existed during the Spokane rather than

the Wisconsin ice-stage. With the final drainage of these bodies of water due to the deepening and widening of the Drumhellar channels and the Columbia canyons, wind-work and erosion again became more active.