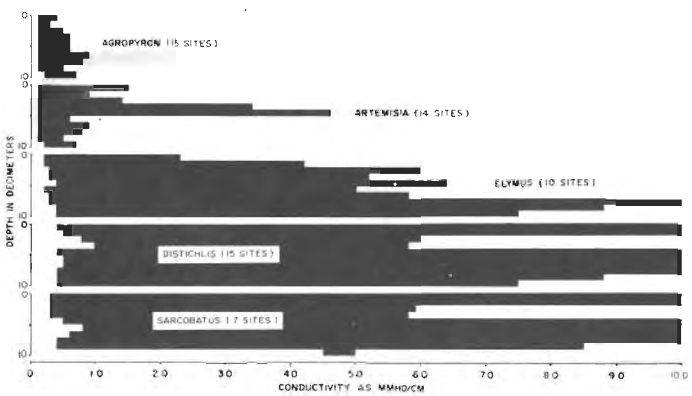
28. Stand of *Sarcobatus vermiculatus-Distichlis stricta* east of Satus, Yakima County, Washington.

considered, possibly soil aeration, or salinity intensification during late summer. *Artemisia tridentata* is commonly associated with *Sarcobatus* in habitats that otherwise would pass as *Sarcobatus-Distichlis* h.t., but is not commonly associated with *Elymus* and *Distichlis.* This closer affininity



29. Total observed ranges of conductivity by decimeter horizons. For the soils supporting *Agropyron,* all soils were sampled to a meter depth; but in some of the other soil groups, high water tables interfered with getting as many samples of the lower horizons as are indicated. The high salinities for *Artemisia* were all obtained at a site that was not sampled below 5 dm, and it might be expected that the values continued to increase with depth.

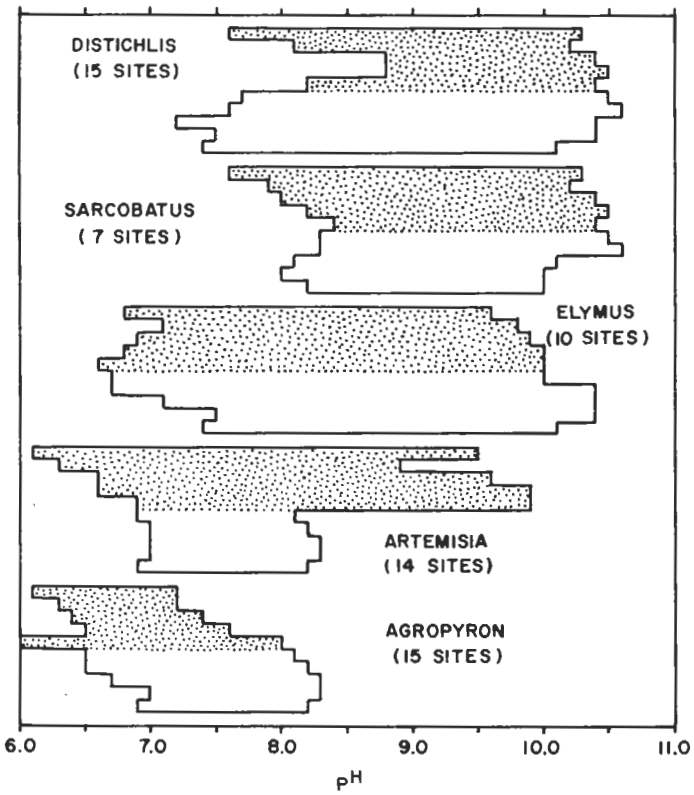
of *Artemisia* with *Sarcobatus,* considered in respect to its well-known sensitivity to poor soil aeration, strengthens the topographic inference as to a difference in aeration requirements of *Sarcobatus* and *Elymus.*

Rickard (99) has observed *Artemisia tridentata* dying in a stand where it is mixed with *Sarcobatus.* The soil here has been eroding because of excessive grazing in the past. Therefore, he interpreted the changing shrub ratio as the result of loss of a relatively nonsaline surface layer on which the *Artemisia* has been dependent, so that a greater proportion of the profile is now saline. Other relevant data on the ecology of *Sarcobatus* in Washington have been presented by Rickard and Cline (100, 101, 102, 103).

The *Sarcobatus-Distichlis* association has been reported for Oregon by Poulton (94), and I have seen stands in Wyoming, Utah and Nevada. In Washington it has not been seen except in the *Artemisia tridentata-Agropyron* and *Artemisia tripartita-Festuca* zones.

Nonsaline soils that are more moist than zonal soils

Here are included deciduous forest and woodland or tall scrub occurring within the general limits of the steppe region, and where the dominance of these life forms is obviously related to more abundant and dependable supplies of soil moisture than are provided by zonal soils.



30. Total ranges of observed soil pH by decimeter horizons. Limitations indicated in figure 29 also apply here. The area representing the upper 5 dm has been stippled to facilitate separate visual comparisons among upper and lower soil levels.

Only the best-defined types of riparian forest and woodland are treated, since there appears to be considerable variety to vegetation in this category, little total area is involved, and disturbance has been so widespread that much time would be required to define all the reasonably distinct habitat types. Extensions of coniferous forest into the steppe region, as on certain lithosols or the protected slopes of deep valleys, have been considered in a previous study (29).

Crataegus douglasii-Symphoricarpos albus h.t.

Distinguishing criteria of climax vegetation in the *Crataegus-Symphoricarpos* h.t. are the presence of an almost complete cover of woody plants about 5-7m tall, in which *Crataegus douglasii* is dominant, the presence in the undergrowth of *Symphoricarpos albus,* and often of *Spiraea betulifolia* as well. The sharing of herbs common to the *Festuca-Symphoricarpos* association is also highly diagnostic, especially *Achillea millefolium, Besseya rubra, Galium boreale, Geranium viscosissimum, Iris missouriensis, Lithophragma parviflora, Potentilla arguta,* and *P. gracilis. Heracleum, Hydrophyllum fendleri,* and *Populus* are unrepresented.

Crataegus stems are usually clustered from the base or from a point just a few dm above the soil surface. Since many of the thorny shade-killed lower branches persist indefinitely, the vegetation has much the character of a thicket, through which it is difficult for a person to make his way. *Amelanchier alnifolia* and *Prunus virginiana,* shorter in other steppe h.ts., commonly grow tall enough here to become minor constituents of the dominant canopy. *Crataegus columbianum* is occasionally represented in small amounts. Coverage of this tall shrub overstory usually varies between 65-100%.

Coverage of the medium shrub layer varies inversely with the denseness of the canopy overhead (appendix B-14). This layer is represented by the *Symphoricarpos* union (*Symphoricarpos albus, Rosa nutkana, R. woodsii,* and *Spiraea betulifolia*) that occurs also as an element of the herb layer in the *Festuca-Symphoricarpos* association, dominates the shrub phase of the latter, then forms the characteristic undergrowth of *Pinus ponderosa-Symphoricarpos* and *Pseudotsuga menziesii-Symphoricarpos* forests in the surrounding mountains (29).

In the herb stratum of the *Crataegus-Symphoricarpos* association, *Montia perfoliata* and *Galium aparine* are the most characteristic plants, even if they are not diagnostic.

Presumably because of the sudden and heavy leaf cast in autumn, epigeous cryptogams are lacking. However, mosses tend to cover all of about the lower 3dm of the *Crataegus* trunks, dwindling upward to a maximum elevation of about 3m. Fine textured lichens cover most of the remaining bark surface, but are not conspicuous.

Crataegus stands support a rich avifauna, relative to other components of the vegetation mosaic, even during the leafless period (45). The berries dry on the twigs and supply significant amounts of food for fructivorous birds, at least in autumn. The divaricately branched stems seem to have special attraction for cover and nesting. Black-billed magpie nests are built mainly in *Crataegus* crowns, and long-eared owls then find the tops of old magpie nests good foundations for nests of their own. Some of the smaller birds such as thrushes and vireos inhabit only the *Crataegus* of steppe vegetation and seem unable to accommodate themselves to city living. These are doomed to disappear as the *Crataegus* thickets are eliminated from the countryside, and this is being effected rapidly by the use of herbicides. Rickard (96) has provided data on small mammal population (appendix D).

Cattle readily eat all *Crataegus* foliage that is within reach, as well as the shrubs and herbs beneath. Grazing tends to replace the community with a sward of *Poa pratensis* (often with *P. compressa* also), in which alien forbs are represented especially by *Cirsium vulgare, Dipascus sylvestris,* and *Taraxacum. Arctium minus* is characteristic of disturbed places that are still shaded. The *Poa* sward that is favored both by heavy grazing and herbicide elimination of the *Crataegus* provides better grazing than the natural vegetation. For the most part, the slopes on which this vegetation occurs are too steep to be cultivated without inviting disastrous slumping of the upper soil horizons. The remaining fragments of *Crataegus*-dominated vegetation are all so modified by grazing that quantitative data have been taken at only the reconnaissance level.

Generalized descriptions of landscapes in the *Festuca-Symphoricarpos* zone prepared by surveyors in 1875 do not mention *Crataegus* vegetation. Had these thickets been

well represented, it seems incredible that they would have failed to mention such a source of inconvenience to anyone who had to cross and recross major valleys. It seems reasonable to assume that the pattern of *Crataegus* stands in eastern Washington, as described in this report is natural, and hypothesize that fire at some period prior to the land survey had reduced the populations to coppice.

The alternative hypothesis of recent invasion is unlikely because:

1. The present stands are of similar age and development.
2. Everwhere the old trees are multiple-stemmed.
3. Recent invasion would undoubtedly involve severe disturbance, but the *Crataegus* habitats are not in vulnerable situations and for the most part are on soils that have never been cultivated.

There is no record of frequent firing of steppe or burning by aborigines, and no aspect of their economy would have benefitted therefrom. It seems much more likely that the hypothecated period of burning was coincident with the early period of white settlement.

The first wave of settlement followed the discovery of gold just east of the steppe in Idaho. When this mineral resource proved small, many of the disappointed fortune-hunters chose to remain in the area. Agricultural statistics for Whitman County from the 1870 census appear unavailable, but Walla Walla County at that time was producing 242,740 bushels of cereal grains per year (120). Production in Whitman County was not far behind (93). Considering the low yield per acre at that time, a fairly large amount of land with post-harvest stubble must have been burned each year to facilitate tillage. There was little incentive or technology for preventing the spread of these fires over the landscape.

Results of agronomic research and improved technology later discouraged farmers from stubble-burning after the wheat harvests. As the numbers and sizes of fires decreased, *Crataegus* thickets redeveloped from stump sprouts.

In addition to the absence of reference to *Crataegus* thickets in descriptions of the townships at the time they were surveyed, five other bits of evidence support the hypothesis of an interlude of burning.

1. The multiple-stemmed form of nearly all *Crataegus* plants suggests origin of the aerial parts from root systems that survived after the shoots were removed.
2. The dead but persistent lower branches of the present stands could be largely a consequence of their development when the stands were more open.
3. King (71) has commented that bird records made at the start of this century show that the black-billed magpie was a rare bird, and only a summer resident at that, in the *Festuca-Symphoricarpos* zone. Most of its population at that time was associated with woody vegetation (*Celtis douglasii, Populus trichocarpa, Alnus rhombifolia,* etc.) along the Snake River and tributary ravines. By contrast, at mid-century King (71) notes the bird as a common year-around resident of the *Festuca-Symphoricarpos* zone. There, it is characteristic of high thickets with by far most of its nests in *Crataegus.* If *Crataegus* had been reduced to stump sprouts by frequent fires at the start of the century, the elimination of its preferred nesting cover would have restricted the bird to the Snake River Canyon, with subsequent expansion out of the Canyon as fires diminished and the *Crataegus* plants grew to their maximum size.
4. A series of photographs of one landscape spanning the period 1916-1968 clearly documents the rapid development of a *Crataegus-Symphoricarpos* stand during a period when the hypothecated sequence would have been operating (figs. 31, 32, 33).
5. Finally, the abundance in *Crataegus* thickets of herbs that are much better represented in the *Festuca-Symphoricarpos* association, and are now in very poor vigor and vitality in the thickets, suggests their possible interpretation as relics from a period of less shade. As pointed out earlier, these herbs are highly tolerant of late summer fires.

McMinn (81) made comparative studies of soil temperature (at 20 cm) and soil moisture during one summer. He found that the soil in *Crataegus-Symphoricarpos* stands was consistently cooler than in stands of the *Festuca-Symphoricarpos* association and its shrub phase. The profile under *Crataegus* had dried to the wilting coefficient only to a depth of 5 dm by later summer. The other two steppe communities dried out dinstinctly faster.

Crataegus-Symphoricarpos stands occur on all directions of exposure. On northerly slopes, the higher moisture status can be explained simply on the basis of reduced insolation, possibly aided by precipitation blown over the ridge summits. On southerly exposures, the high moisture demand may be satisfied by horizontal drainage over the surface of basalt strata that bring water near the surface along valley sides. On these slopes, the *Crataegus-Symphoricarpos* stands commonly form ecotones with stands of the very xerophytic lithosolic *Agropyron-Poa* association. The latter are apparently limited to places where basalt approaches the soil surface without bringing significant water with it, or with the shrub phase of the *Festuca-Symphoricarpos* association where moisture conditions are intermediate. Because the *Crataegus-Symphoricarpos* stands are independent of direction of slope and require only above-average soil moisture, the association is considered an edaphic climax.

Major valleys in the *Festuca-Symphoricarpos* zone commonly support *Pinus ponderosa-Symphoricarpos albus* forest on the sheltered slopes. Corresponding topography in ravines that branch off to the side support *Crataegus-Symphoricarpos* stands. McMinn's (81) study of soil moisture conditions in summer showed that the soils of the latter retain moisture better than soils under the pine.

The *Crataegus-Symphoricarpos* h.t. seems confined to the *Festuca-Symphoricarpos* and *Festuca-Rosa* zones.

Populus tremuloides phase

At frequent intervals over the range of the *Crataegus-Symphoricarpos* association there occur stands apparently normal for that association both as to biotic and physical features, except that *Populus tremuloides* is well represented (appendix B-14). An interesting microseral phenomenon seems to characterize these stands. *Populus* can grow up through a *Crataegus* canopy, ultimately reaching twice its height, and when overtopped the *Crataegus* starts to decline progressively. However, the *Populus* is subject

31. Remnant of virgin steppe still preserved on the campus of Washington State University, as photographed by H. L. Shantz September 2, 1916. The isolated multiple-stemmed *Crataegus* on the ridge summit appears to have no living foliage below about 1.5 m. This is not likely a consequence of grazing, since the herbaceous cover in the foreground shows no use. It could well result from fire creeping across partially dried grassland in midsummer. A line of shrubs has developed along the fence in the distance.

to heart rot and therefore short-lived. The population as a whole dies back to the ground when the trees reach a diameter of about 2 dm at breast height and appear to be about 50 years old. The *Populus* collapse allows the regeneration of the enfeebled *Crataegus*, which then redevelops a nearly complete canopy before root sprouts of the *Populus* appear and start to grow up through it again.

This phase of the *Crataegus-Symphoricarpos* h.t. seems worthy of recognition because the distinction between *Crataegus* stands that are permanent and those in which dominance seems to alternate between *Crataegus* and *Populus* is sharp, and may well reflect some subtle ecologic difference.

The unit recognized above is clearly distinguished from a closely related *Populus tremuloides-Symphoricarpos albus* association that is much more widespread in the northern Rockies (77) and on the east slope of the Cascade Mountains. But the unit lacks the *Crataegus* layer, and so far as is known is not subject to repeated episodes of simultaneous stem dieback.

Crataegus douglasii-Heracleum lanatum h.t.

Climax vegetation in the *Crataegus-Heracleum* h.t. consists of a nearly complete cover of woody plants growing about 5-7m tall. Among these *Crataegus douglasii* is most most dominant, combined with an undergrowth in which *Heracleum lanatum, Hydrophyllum fendleri* and *Urtica dioica* dominate, either singly or collectively. *Rosa* and *Symphoricarpos* are at most poorly represented in this h.t., but will invade disturbed areas readily.

Except for *Lomatium dissectum,* the *Crataegus-Heracleum* association shares no significant floristic features with the *Festuca-Symphoricarpos* or *Festuca-Rosa* associations of adjacent uplands. This stands in sharp contrast with the *Crataegus-Symphoricarpos* association.

On the other hand, the *Crataegus-Heracleum* association frequently contains elements more common in forests of the adjacent mountains, such as *Circaea alpina, Cornus stolonifera, Elymus glauca, Geum macrophyllum, Osmorhiza chilense, Pteridium aquilinum.* This association fur-

32. View similar to figure 31, as photographed May 7, 1939. In this photo, the camera point was far forward of that in figure 31. The isolated, multiple-stemmed *Crataegus* on the ridgetop was present then, but outside the field of view. The coverage and height of the woody vegetation, including the *Prunus virginiana*-dominated strip along the fence, obviously increased in the 23 years after figure 31.

33. View similar to figure 31 as photographed in 1968. Twenty-nine more years have allowed still further expansion of the woody vegetation. The formerly isolated *Crataegus* is surrounded by what are probably clonal offspring.

ther differs from the *Crataegus-Symphoricarpos* association by being more susceptible to invasion by perennial herbaceous aliens.

The overstory of the *Crataegus-Heracleum* association is essentially like that of the *Crataegus-Symphoricarpos* association. Beneath the trees the *Heracleum*, a coarse herb, usually grows well over 2m tall (fig. 34) penetrating the lower part of the thorny tangle of persistent branches of the *Crataegus*. It produces many large leaves held horizontally, and these intercept nearly all the light filtering through the *Crataegus* canopy. This double screening of incident radiation must play a major role in reducing the numbers of shorter plants that can get established below the *Heracleum*, at least limiting those which cannot develop in spring before the *Heracleum* foliage expands. Even though the stand sizes were not closely standardized so that precise comparisons are justified, it is evident in comparing appendices B-14 and B-15 that a distinctly lower species diversity characterizes the *Crataegus-Heracleum* association.

Where a small disturbance allows *Rosa* to get established, it grows as least as tall as the *Heracleum* (which *Symphoricarpos* cannot do), presumably in response to the crowding and to favorable moisture and fertility. Mosses on the bark tend to be more conspicuous and to extend farther above the ground than they do in the *Crataegus-Symphoricarpos* association.

Cattle eat *Heracleum* readily; a colloquial name for the plant is "cow parsnip." But the plant withstands grazing poorly, and so is easily eliminated, with a *Poa pratensis* meadow taking its place. Alien weedy perennials accompanying the *Poa* include *Artemisia absinthinum, Cirsium vulgare, Dipsacus sylvestris, Marrubium vulgare, Tanacetum vulgare* and *Taraxacum. Arctium minus,* another alien favored by disturbance, is mainly confined to areas still well shaded by *Crataegus*. While *Heracleum* grows luxuriantly and fruits vigorously in the shade of a *Crataegus* canopy, it performs equally well, even if the stature is shorter, when the canopy is removed, providing the area is not grazed (fig. 35).

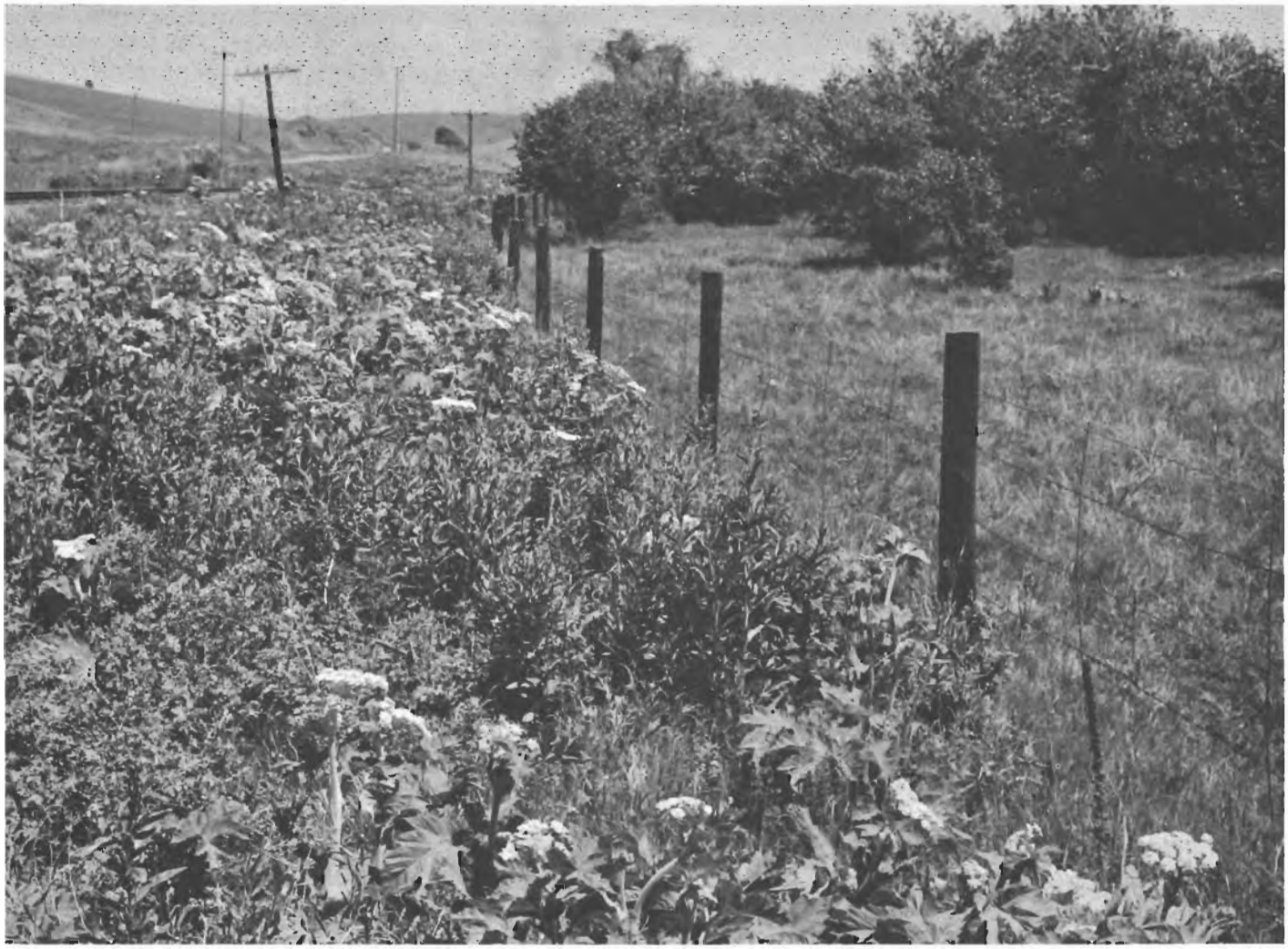
The *Crataegus-Heracleum* h.t. is primarily characteristic of aggraded valley floors (locally called "flats") which border intermittent or permanent creeks. These valleys were probably V-shaped during late glacial time, then accumulated fills of silt-plus-clay during the Hypsithermal interval. Today, vertical-walled trenches are being cut through those fine sediments. The *Crataegus-Heracleum* h.t. is, however, not confined to valley floors. It often extends up contiguous northerly slopes, sometimes to more than 15m above the valley floor where seepage water comes practically to the soil surface, and even higher along the bottoms of V-shaped ravines opening onto the major valleys.

Valley floors representing the *Crataegus-Heracleum* h.t. are typically bordered by the *Crataegus-Symphoricarpos* h.t. on the contiguous north-facing slope, and by the lithosolic *Agropyron-Poa* h.t. on the opposite slope. The h.t. is homologous with the *Populus trichocarpa-Cicuta* h.t. in a slightly drier climate, and with the *Elymus cinereus-Distichlis* h.t. in an environment still drier where salts

34. *Crataegus douglasii-Heracleum lanatum* stand on Union Flat Creek west of Pullman, Washington. *Heracleum* in essentially the same density as in this small opening extended back under the *Crataegus*.

can accumulate in the soil. Scattered individuals and clumps of *Elymus cinereus* are common in the ecotone between *Crataegus-Heracleum* and the lithosolic *Agropyron-Poa* associations. However, these spots have normal pH and solute content, and the soil profiles show no evidence of having been salinized during the Hypsithermal period.

Until a few years ago, a plantation of *Ulmus* growing a few miles northwest of Pullman, Washington, occupied parts of a slope and the contiguous "flat." Beneath the *Ulmus*, a typical stand of the *Symphoricarpos* union had redeveloped on the slope after the disturbance caused by cultivating and planting an exotic tree. At the foot of the slope, this gave way to a stand of the *Heracleum* union. Before the invasion of white man, both topographic positions undoubtedly supported a cover of *Crataegus*. This



35. This valley bottom near Pullman, Washington, once bore a nearly complete cover of *Crataegus douglasii* (deciduous low tree to right) with an understory of *Heracleum lanatum* (flowering herb to left of fence). To the left of the fence, crews maintaining the railway right-of-way removed the *Crataegus,* then continued to destroy new shoots as they appeared. To the right of the fence, cattle have brought about a complete replacement of the *Heracleum* by *Poa pratensis* without significant damage to the *Crataegus.* Two zootic climaxes have been derived from the same edaphic climax. Since this picture was taken, the *Crataegus* has been destroyed by herbicide applied aerially.

situation showed quite clearly the independent occupancy of sites by forest overstory and understory, which is equally conspicuous in coniferous forest in the nearby mountains (29).

The *Crataegus-Heracleum* h.t. is confined to the wetter parts of the *Festuca-Symphoricarpos* and *Festuca-Rosa* zones. In the aggregate, it includes considerable area. The flatness of the valley floors, combined with their deep soils and favorable moisture relations have resulted in nearly all of the h.t.'s being taken over for grain cropping or permanent pasture. One of the colloquial names for *Crataegus* is "thorn," and the village of Thornton, Washington, was probably so named because it was in a "flat" which, to judge from the topography, must certainly have been covered by *Crataegus* when white man settled the area.

Populus tremuloides phase

The *Crataegus-Heracleum* association is locally replaced by a variant that has an intermittent *Populus tremuloides* overstory. The *Crataegus* and *Populus* canopies here have apparently the same relationship to each other as in the *Crataegus-Symphoricarpos association* and its *Populus tremuloides* phase (fig. 36).

Two other minor variants of stream terraces supporting *Crataegus* deserve mention. In places, *Populus trichocarpa* borders the stream, rising high above the *Crataegus* canopy that covers the remainder of the terraces on either side. It is possible that this tree was much more abundant before the arrival of white man, and that early settlers made heavy use of the only fairly large tree present in the steppe. *Salix* spp. and *Alnus tenuifolia*

are also occasionally encountered along waterways, but they are not so abundant as the *Populus trichocarpa.*

On a few stream terraces, *Pinus ponderosa* is superimposed over the *Crataegus* layer. Examples can be seen in the Lewis and Clark State Park, 2 miles east of Waitsburgh, in Columbia County, Washington, and in the valley of Paradise Creek a few miles east of Pullman, in Whitman County.

Populus trichocarpa-Cicuta douglasii h.t.

The *Crataegus-Heracleum* h.t., which characterizes valley floors in the wetter part of the *Festuca-Symphoricarpos* and *Festuca-Rosa* zones, is replaced geographically on approaching drier climates by a distinctly different homolog that is botanically distinct in both major layers. *Heracleum* is replaced by *Cicuta douglasii,* another tall herb in the *Umbelliferae. Crataegus* yields its overwhelming control of the overstory to *Populus trichocarpa* (fig. 37).

This h.t. extends well out into the contiguous *Agropyron-Festuca* zone. For example, it lines the Palouse River from a point about 5 miles ESE of Colfax on the South Fork, to where this river forms the boundary between Whitman and Adams Counties. It also lines Lapwai Creek between Spalding and Culdesac, Idaho. Everywhere the vegetation has been even more completely disturbed than the *Crataegus-Heracleum* association, and so has not been amenable to study. The best remaining fragments are along Lapwai Creek near Lapwai.

Alnus rhombifolia h.t.

Narrow valleys emptying into the Snake River in Whitman and Asotin Counties have a strip of *Alnus rhombifolia*-dominated forest along the waterway (fig. 38). This *Alnus* grows to about 13m tall and 6dm in diameter, which makes it second in size to only *Populus trichocarpa* among our deciduous trees. The two are associated where the valleys are broad enough to have much of a floodplain.

At its lower end, this strip typically abuts the *Celtis douglasii* h.t. on alluvial cobble that is deposited at the mouth of the valley. The *Agropyron-Festuca* or *Agropyron Poa* h.t. occur on contiguous valley sides, depending on the degree of exposure to the sun.

Other special soils

Purshia tridentata-Agropyron spicatum h.t.

Natural vegetation in the *Purshia-Agropyron* h.t. consists of an open medium-shrub layer of *Purshia tridentata; Agropyron spicatum* provides most of the bulk of the herb

36. Small stand of the *Populus tremuloides* phase of the *Crataegus-Heracleum* association in which the *Populus* overstory has recently died. Root sprouts of the *Populus* can be expected to appear within a few years. Shawnee, Whitman County, Washington.