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PINE FORESTS AND SPARSE ARID-PETROPHYTIC STANDS IN CENTRAL KAZAKHSTAN, THEIR CHARACTERISTICS AND ANTHROPOGENIC DYNAMICS

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Highly unique common-pine communities were characterized near the southern limit of common-pine distribution in granite foothills of the Kazakhstan steppe zone. Changes in these communities under the influence of human activity were studied.

The zonal vegetation in Central Kazakhstan [or the Central Kazakhstan physiogeographic nation of N. A. Gvozdetskii and V. A. Nikolaev (1971); the Central Kazakhstan hill country of B. A. Fedorovich (1969)] is represented by steppes. However, scattered forest cases consisting of more or less large tracts of common-pine (*Pinus sylvestris*) communities are present against the background of this predominant vegetation type.

The terrain of Central Kazakhstan is one of plains and hill country and occasional foothills; it is characterized by small coniform hills (which is why this region is frequently called the hill country), rolling hills, and insular foothills composed of granite intrusions. Pine forests and stands, as well as individual pine occurrences, are primarily associated with severely eroded foothills.

The insular pine forests of Central Kazakhstan are subdivided into two main groups, the Kokchetavskaya and Bayanaul'sko-Karkaralinskaya groups. The first is located in the forb—feather grass steppe subzone, the second in the dry fescue—feather grass steppe subzone.

In the feather grass—forb steppe subzone pine is almost everywhere associated with granites, but it is sometimes also encountered on outcrops of quartz and schists, as, for example, in the Koturkul'skoe forest of the Borovskii tract. However, pine was formerly distributed on rocks of nongranite composition. Thus, 150 years ago the slopes of the porphyrite cone Dzhaksy-Dzhangiztau were covered with pine forest; today only a few individual pines remain.

In the fescue—feather grass steppe subzone pine is associated exclusively with granite foothills and is absent outside their limits. The growth of pine under azonal conditions which are so untypical for it is mainly determined by the properties of the substrate: the pillow stratification of the granites, their increased fracturing, the granular structure and light mechanical composition of weathering products, the weak mineralization of the ground and interstitial water, and the condensation of atmospheric moisture in deep fractures. Furthermore, a definite role is also played by the uplift of the granite intrusions above the level of the surrounding locality, which provides for a marked zonation of the climate and vegetation. Along with pine forests, unique sparse pine stands are encountered in forest cases; in some cases the latter even exceed the pine forests in area.

While the pine forests of Central Kazakhstan have already served as the subject of specialized investigation (Gordyagin, 1897; Sukahcev, 1948; and others), although they have thus far been characterized only in the most general terms, this cannot be said of the sparse pine stands. Until recently they have remained nearly unstudied [with the exception of the work of A. D. Tokarev (1969), which examined them from forestry and sylvicultural points of view] and have not been included in attempts to classify the forest vegetation of Kazakhstan (Gribanov, 1965a), while their ecological and phytocenotic characteristics remain unknown.

On the basis of investigations conducted in 1978-1980, the present paper describes (using the Bayanaul'skii forest tract) the pine forests and arid-petrophytic sparse stands in Central Kazakhstan and examines their characteristics and anthropogenic dynamics.

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The investigations were conducted in Bayanaul'skii pine tract in Pavlodar Province, Kazakh SSR. The Bayanaul'skie foothills (highest point is Akpet at 1027 m above sea level) occupy an oval area (approximately 20 × 40 km) and represent a severely eroded granite intrusion. According to B. P. Alisov (1956), the region investigated belongs to the "continental steppe, West Siberian zone," which, as noted by N. A. Gvozdetskii and V. A. Nikolaev (1971), would more correctly be called the "continental steppe, Kazakhstan zone." This zone is characterized by considerable annual and daily temperature changes, a high insolation, the predominance of summer rainfall over winter, frequent repetition of summer droughts, and a short growing season. However, the continentality of the climate is somewhat moderated in the granite foothills as a result of their uplift above the level of the surrounding locality. According to the observations of Bayanaul Meteorological Station (*Handbook on the Climate of the USSR*, 1966, 1968), the mean annual temperature is 3.3°, the mean January temperature is −13.2°, and the mean July temperature 20.5°. The mean annual rainfall is 401 mm.

The Bayanaul'skie foothill massif is located in the steppe zone, in the dry fescue—feather grass subzone. Insofar as the massif rises above the level of the surrounding locality, it bears pronounced altitudinal plant zonation with both forest-steppe and forest zones (Karamysheva, 1961). The vegetation of the mountains is primarily forest, with a predominance of common-pine communities. A smaller area is occupied by birch and aspen forest. Relic black alder forests are encountered along stream beds (Gorchakovskii and Lalayan, 1981).

The vegetation in the locality adjacent to the massif, in low hill country and in diluvial—slopewash depressions between hills, is dominated (*Vegetation Map of Kazakh Hill-Country Steppe*, 1975) by series of communities of *Helictotrichon desertorum* and *Stipa capillata* formations with *Caragana pumila*, agricultural lands instead of forb—*Helictotrichon desertorum*—*Stipa rubens* steppes, and *Caragana pumila*—*Festuca valesiaca* subsp. sulcata—*Stipa sareptana* steppes. The steppe communities are associated primarily with dark chestnut poorly developed and incompletely developed gravel soils as well as chestnut soils on dense crystalline rock (*Soil Map of Kazakh SSR*, 1976).

Patterns of plant distribution were determined during field work by transect investigations. To describe the communities with pine 46 sample plots, each of 0.25 ha area, were set out; the trees on these plots were counted noting the distribution with respect to trunk diameter and the shrub, herbaceous, and moss—lichen tiers were described. Anthropogenic changes in the vegetation were studied by selecting series of sample plots with a plant cover originally uniform but in varying degree subjected to degradation. Certain treeless communities derived from pine communities (rocky deserts, shrub thickets, and steppe) were also described.

The identification of plant associations by the dominant species involves considerable difficulty in pine forests located at the limit of pine distribution and especially in sparse stands, where the edificatory role of pine has been greatly weakened or totally lost. The grassy cover is very poorly expressed in many communities, and it is frequently impossible to identify within it any plant species which are actually dominant. On the other hand, if dominant species are present they usually have a broad ecological amplitude and may be abundantly encountered in different associations. Therefore, associations were identified on the basis of indicator species. These are species that are the most characteristic for a given community or aggregate of communities, that to the greatest extent reflect the environmental conditions, and are distinguished by a high constancy and sometimes by the life state. Indicator species best characterize a given association and at the same time permit its differentiaton from surrounding associations.

INDIGENOUS PLANT COMMUNITIES

The plant communities with pine in the woody tier that have been changed little by human activity (indigenous or quasinatural communities) are represented in the study region by four principal associations. Their distribution with respect to terrain is shown in Fig. 1. These associations are arranged in a single ecological series from the least moist habitats with an unstable moisture regime and rudimentary soil (see Fig. 1a) to moderately moist habitats with a more stable moisture regime and a rather well-developed soil (Fig. 1d). This series is simultaneously a genetic series, since it reflects the natural trends of change in environmental conditions and vegetation, determined by the extent of weathering of granite rocks, block pulverization, fine-earth accumulation, and soil formation.

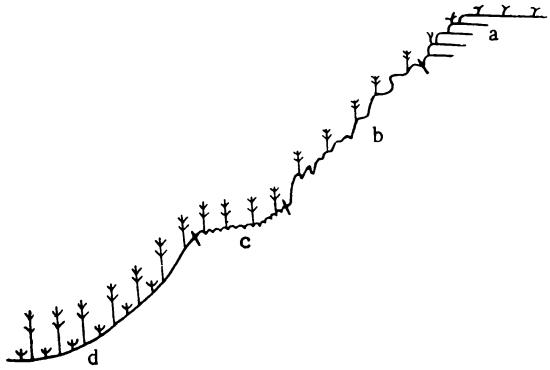

Fig. 1. Contour distribution of principal indigenous plant associations with pine in the woody tier: a) sparse pine stand on pillow platforms with *Dasiphora parviflora*, b) rocky—craggy pine forest with *Sedum hybridum* and *Veronica incana*, c) rocky—lichen pine forest with *Antennaria dioica*, d) shrubby pine forest with *Cotoneaster melanocarpa* and *Rosa spinosissima*.

Sparse Pine Stand on Pillow Platforms with *Dasiphora parviflora*. These stands are encountered on water-shed and relic ridges, on steep (15-28°) eroded slopes of granite coniform hills of primarily southern, southwestern, and southeastern orientation, and on outcrops of pillow granite platforms. Granite platforms and strata of up to several tens of centimeters thick are superimposed upon one another. The platform surfaces are bare, and only in the numerous fractures and breaks have the fine-earth products of granite weathering been accumulated. The soil is a rudimentary primitive—accumulative sandy loam with gruss, developed only in the gaps between platforms where a small quantity of fine earth has accumulated, and covers no more than 10-20% of the surface. The depth of the fine-earth layer at sites of accumulation reaches 10 cm, rarely 20 cm. The soil in fine-earth patches has the following structure*:

A_0A_1 (0-10 cm). Sandy loam of a gray coloration, fine aleurite with white patches of granite gruss and abundant semidecomposed plant remains.

C (10 cm and deeper). Granite platform.

The woody tier is weakly developed, consists of pine with small numbers of birch (*Betula verrucosa*) and aspen (*Populus tremula*), and is sparse with a a crown density of no more than 5-10%. The pine is bunched into gaps between granite blocks, is short, and deformed with certain specimens of a shrub or dwarf form. The site class is Vb, the trees average 3-5 m in height with a maximal height of 7 m, and the mean diameter is 20 cm. The wood supply is from 15 to 32 m^3 per 1 ha.

The shrubby tier is very poorly developed with a projective cover of no more than 5%. It includes the most characteristic species in this association, the low shrub *D. parviflora* (sol.-sp.), which has high constancy and finds here the optimal conditions for its existence. Other species include *Spiraea hypericifolia* (sol.-sp.), the creeping shrub *Juniperus sabina*, which spreads by the growth of roots from branches in the form of groves of 10-12 m in diameter, *Rubus idaeus* (sol.), and others.

The herbage (see Table 1) is very sparse (projective cover of 5-20%), and the plants are concentrated in gaps between platforms and in fractures in the granite blocks, where a fine earth is accumulated. The most constant in this tier are: *Sedum hybridum* and *Chamaenerion angustifolium* (sp.-cop.$_1$) and *Polygonum convolvulus, Asplenium septentrionale,* and *Woodsia ilvensis* (sol.). Of interest is the appreciable presence in the herbage of herbaceous petrophytes, small petrophilous ferns, and alliaceous geophytes (species of the genus *Allium*).

Mosses and lichens grow on weathered-granite platforms, covering 20-40% of the surface.

*Here and below the descriptions of typical soil sections are used to characterize soils.

TABLE 1. Foristic Composition of Herbaceous Cover (abundance according to the Drude scale)

No.	Plant names	Subtier	Pine forest			Sparse pine stand	
			rocky—craggy	rocky—lichen	shrubbly	indigenous on pillows	derivative rocky—craggy
1	— *Achillea nobilis* L.	II	sp.	sol.	sp.	sol.	sol.
2	— *Achyrophorus maculatus* (L.) Scop.	I	sol.	—	sol.	—	—
3	— *Adonis vernalis* L.	II	—	—	sol.	—	—
4	+ *Allium globosum* M. B. ex Redoute	II	sol.	sol.	—	sol.	sol.
5	+ *A. lineare* L.	II	sol.	sol.	—	—	—
6	+ *A. nutans* L.	II	sp.	sol.	—	sp.	sol.
7	+ *A. rubens* Schrad. ex Willd.	II	—	—	—	sol.	—
8	+ *A. senescens* L.	II	sol.	sol.	—	sol.	sol.
9	+ *A. strictum* Schrad.	II	sol.	sol.	sol.	sol.	—
10	— *Anemone sylvestris* L.	II	—	—	sol.	—	—
11	! *Antennaria dioica* (L.) Gaertn.	III	—	sol.	sol.	—	—
12	*Arenaria graminifolia* Schrad.	II	—	—	sol.	—	—
13	— *Artemisia armeniaca* Lam.	II	sol.	—	—	sol.	—
14	* *A. dracunculus* L.	I	—	—	—	—	sol.
15	+ *A. frigida* Willd.	II	sol.	—	—	sol.	—
16	— *A. sericea* Web. ex Stechm.	II	sol.	—	sol.	sol.	sol.
17	*Asparagus officinalis* L.	I	—	—	sol.	—	sol.
18	+ *Asplenium septentrionale* (L.) Hoffm.	III	sol.	sol.	—	sol.	sol.
19	* *Berteroa incana* (L.) DC.	II	sol.	sol.	—	sol.	sol.
20	*Calamagrostis epigeios* (L.) Roth.	I	—	—	sol.	—	sol.
21	* *Cannabis ruderalis* Janisch.	II	sol.	—	—	sol.	—
22	— *Carex ruthenica* V. Krecz.	III	—	sol.	—	sol.	—
23	— *C. supina* Wahl.	III	sol.	—	sol.	—	—
24	— *Centaurea sibirica* L.	III	—	—	sol.	—	sol.
25	* *Cerastium arvense* L.	III	—	—	sol.	—	—
26	* *Chamaenerion angustifolium* (L.) Scop.	I	$cop._1$	sol.	—	$cop._1$	sp.
27	* *Chelidonium majus* L.	II	—	—	—	sol.	—
28	* *Chenopodium album* L.	II	sol.	sol.	—	sp.	sol.
29	! *Cystopteris fragilis* (L.) Bernh.	III	—	—	sol.	—	—
30	— *Dracocephalum ruyischiana* L.	III	—	—	sol.	—	—
31	— *D. thymiflorum* L.	II	sol.	—	—	—	—
32	+ *Euphorbia humilis* C. A. Mey ex Ledeb.	I	sp.	sol.	sol.	sol.	sp.
33	— *Festuca valesiaca* Gaud. subsp. *sulcata* (Hack.) Schinz	III	sol.	sol.	sp.	sol.	sol.
34	— *Filipendula vulgaris* Moench.	I	—	—	$cop._2$	—	—
35	*Fragaria vesca* L.	III	—	—	sol.	—	—
36	— *F. viridis* Duchartre.	III	—	—	$cop._1$	—	—
37	* *Fumaria officinalis* L.	II	sol.	sol.	—	sol.	—
38	! *Galium boreale* L.	II	—	—	$cop._1$	—	—
39	— *G. verum* L.	I	sp.	sol.	$cop._1$	sol.	sol.
40	*Gentiana cruciata* L.	II	—	—	sol.	—	—
41	— *Glycyrrhiza korshinskyi* Grig.	I	sol.	—	sol.	—	sol.
42	+ *Gymnocarpium robertianum* (Hoffm.) Newm.	III	—	sol.	—	sol.	—
43	— *Helictotrichon desertorum* (Less.) Nevski	II	—	—	sol.	—	—
44	*Hieracium asiaticum* (Naeg. et Peter) Juxip.	II	sol.	sol.	—	sol.	sol.
45	*H. umbellatum* L.	II	—	sol.	sol.	—	—
46	*H. virosum* Pall.	I	sol.	—	$cop._1$	sol.	sol.
47	*Hypericum perforatum* L.	I	—	—	—	sol.	—
48	*Inula hirta* L.	II	sp.	—	—	sol.	—
49	*Lactuca tatarica* (L.) C. A. Mey	I	sol.	—	—	—	—
50	*Lathyrus pisiformis* L.	I	—	sol.	sol.	—	—
51	+ *Libanotis buchtormensis* (Fisch.) DC.	II	—	—	—	sol.	sol.
52	*L. sibirica* (L.) C. A. M.	I	sp.	sol.	$cop._1$	sol.	
53	*Linaria vulgaris* Mill.	I	—	—	—	—	sol.
54	— *Medicago romanica* Prod.	I	sp.	—	sp.	sol.	—
55	— *Melandrium viscosum* (L.) Čelak.	II	sol.	sol.	—	sol.	—
56	* *Myosotis sparsiflora* Pohl.	II	sol.	—	—	—	—

TABLE 1. (continued)

No.	Plant names	Subtier	Pine forest			Sparse pine stand	
			rocky–craggy	rocky–lichen	shrubby	indigenous on pillows	derivative rocky–craggy
57	!*Neottianthe cucullata* (L.) Schlechter	III	—	—	sol.	—	—
58	— *Onosma simplicissimum* L	III	sol.	—	sp.	—	—
59	— *Orostachys spinosa* (L.) C. A. Mey	III	sol.	sol.	—	sol.	sol.
60	— *Oxytropis pilosa* (L.) DC	II	sol.	sol.	—	—	sol.
61	+ *Patrinia intermedia* (Hornem.) Roem.	I	sol.	sol.	—	sol.	sol.
62	— *Phlomis tuberosa* L	II	—	—	cop.$_1$	—	—
63	—*Plantago media* L. subsp. *stepposa* (Kuprian.)	III	—	—	sol.	—	—
64	— *Poa stepposa* (Kryl.) Roshey	II	—	sol.	—	—	sol.
65	*Polygala comosa* Schkuhr	II	—	—	sol.	—	—
66	* *Polygonum convolvulus* L	I	sol.	sp.	sol.	sp.	sol.
67	+ *Polypodium vulgare* L	III	sol.	sol.	—	sol.	sol.
68	— *Potentilla argentea* L	I	sol.	—	—	—	sol.
69	— *P. humifusa* Willd. ex Schlecht	II	sol.	—	sol.	—	—
70	— *Pulsatilla patens* (L.) Mill	II	—	—	cop.$_1$	—	—
71	! *Ramischia secunda* (L.) Garcke	III	—	—	sol.	—	—
72	! *Rubus saxatilis* L	III	—	—	sol.	—	—
73	*Rumex acetosa* L. ssp. *thyrsiflorus* (Fingerh.) Stojan. et Steph	I	—	—	—	—	sol.
74	— *Scorzonera purpurea* L	III	sol.	sol.	—	—	sol.
75	+ *Sedum hybridum* L	III	sp.	sp.	sol.	cop.$_1$	sol.
76	+ *S. purpureum* (L.) Schult	II	—	—	sol.	—	sol.
77	!*Senecio erucifolius* L	II	—	—	sol.	—	—
78	*Silene vulgaris* (Moench.) Garcke	II	—	—	sol.	—	—
79	*S. nutans* L	II	sol.	—	sol.	—	—
80	— *Sisymbrium polymorphum* (Murr.) Roth	I	sol.	—	sol.	—	sol.
81	*Stellaria graminea* L	III	—	—	sp.	—	—
82	— *Stipa capillata* L	II	sol.	—	—	—	—
83	* *Taraxacum officinale* Wigg	III	—	—	sol.	—	—
84	— *Thalictrum foetidum* L	II	sol.	—	cop.$_2$	—	—
85	*T. collinum* Wallr	II	—	—	sol.	—	—
86	*T. simplex* L	I	—	—	sol.	—	—
87	— *Thymus marschallianus* Willd	III	sol.	—	—	sol.	—
88	— *Trifolium lupinaster* L	II	—	sol.	sp.	—	sol.
89	— *Tulipa patens* J. Agardh ex Schult	III	—	—	sol.	—	—
90	* *Verbascum thapsus* L	III	sol.	—	—	sol.	sol.
91	— *Veronica incana* L	II	sp.	sol.	sol.	sp.	sol.
92	— *V. spuria* L	I	sol.	sol.	sp.	sol.	sol.
93	— *V. spicata* L	II	sol.	—	—	—	sol.
94	*Vicia cracca* L	I	—	—	sol.	—	—
95	*Viola arenaria* DC	III	—	—	sol.	—	—
96	*V. elatior* Fries	III	—	—	sol.	—	—
97	— *Vincetoxicum sibiricum* Willd	III	sol.	—	—	sol.	—
98	+ *Woodsia ilvensis* (L.) R. Br	III	sol.	sol.	—	sol.	sol.
99	— *Ziziphora crinopodioides* Lam	II	sol.	—	—	sol.	sol.
	Total		52	34	58	41	40
	Including boreal (!)	—	—	1	6	—	
	synanthropic (*)	—	8	5	3	8	6
	forest-steppe and steppe (—)	—	25	12	25	14	17
	craggy (+)	—	12	12	4	14	11

The most characteristic are the foliose lichens *Parmelia saxatilis*, *P. sulcata*, *Umbilicaria pennsylvanica*, *Peltigera malacea*, and *P. rufescens* (cop.$_1$–cop.$_2$), the crustose lichen *Rhizocarpon geographicum* (sp.), and the epilithic mosses *Grimmia laevigata* and *G. montana* (sol.–cop.$_1$).

Rocky-Craggy Pine Forest with *Sedum hybridum* and *Veronica incana*. This association is found on strongly inclined and steep slopes facing the southwest, south, or southeast. The surface is relatively even, but sometimes large blocks and fragments of disturbed granite rise above the surface. A large portion of the surface is denuded, and aggregations of fine earth with soil fragments cover from 25 to 40% of the substrate surface. A friable soil layer of up to 15-25 cm thickness is present, rarely (in the deepest gaps) up to 50 cm. The soil is a fragmentary brown mountain-forest, gruss—light loam; it contains a considerable gruss admixture and is not clearly differentiated into genetic horizons. At sites where fine earth collects the structure of soil fragments is as follows:

A_0. Litter consisting of pine needles, twigs, and cones.

A_1 (1-6 cm). Dark gray, cloddy—aleurite light loam with extensive gruss inclusion.

BC (6-25 cm). Light-brown cloddy—aleurite friable sandy loam, more than 60% quartz—feldspar gruss.

C (25 cm and deeper). Granite blocks.

The tree stand consists of pine with a negligible presence of *B. verrucosa*. The pine grows at sites of soil accumulation, the mean diameter is 24 cm, the maximal 44 cm, the mean height is 8 m, and the maximal 10-12 m. The site class is V, the crown density 30-40%, and the wood reserve 60-90 m^3 per 1 ha.

The shrubby tier is very spare (projective cover less than 5%), 0.5-0.8 m high, and consists of *Juniperus sabina* (sol.-sp.), *Spiraea hypericifolia, Caragana pumila, Rosa cinnamomea,* and *R. spinosissima* (sol.).

The herbaceous tier is weakly developed, its projective cover 20-35%, and the species composition poor. The herbage is clumped in gaps, at sites of fine-earth accumulation. The most constant and characteristic are the succulent petrophyte *Sedum hybridum* (sp.-cop.$_1$) and the xeromorphic facultative petrophyte *Veronica incana* (sp.-cop.$_1$); additionally present are *Galium verum* and *Allium senescens* (sol.-cop.$_1$), *Chamaeneriom angustifolium* (sol.-sp.), *Euphorbia humilis, Orostachys spinosa,* and *Hieracium virosum* (sol.-sp.), *Patrinia intermedia*- and *Hieracium asiaticum* (sol.), and others. It is remarkable that petrophytes and mountain-steppe plants have an appreciable role in the composition of this tier, which is explained by the craggy nature of the substrate.

The moss—lichen tier, covering 10-40% of the substrate surface, consists of the foliose epilithic lichens *Parmelia saxatilis* and *Peltigera malacea* (sp.-cop.$_2$), *Parmelia sulcata* and *Umbilicaria deusta* (sol.-sp.), growing on the surface of blocks and in small fine-earth accumulations, and the mosses *Grimmia laevigata* (sol.-cop.$_1$), *Polytrichum juniperinum* (sol.-sp.), and others.

Rocky—Lichen Pine Forest with *Antennaria dioica*. This association occupies a relatively level location on passes and in depressions between craggy ridges. Outcrops of bare granite blocks are occasionally present on the surface. The soil is a gruss—light loam, weakly developed brown mountain-forest soil and covers 70-90% of the surface. The fine earth is 20-45 cm thick, in places up to 60 cm.

A_0 (0-2 cm). Litter consisting of needles, pieces of bark, and the remains of cones in the lower portion.

A_1B (2-8 cm). Brown light loam with lighter patches and granite gruss, aleurite, friable, and containing numerous decomposed tree roots.

B (8-24 cm). Light-brown evenly colored light loam with abundant gruss, aleurite, and numerous root remains.

BC (24-40 cm). Light-brown evenly colored sandy loam with pale-yellow hue and above 60% granite gruss.

C (40 cm and deeper). Granite blocks.

The tree stand consists of pine with a small admixture of *B. verrucosa*, the site class is IV, crown density 40-60%, and the wood reserve 100-200 m^3 per 1 ha. The average pine diameter is 16-20 cm and the maximal 44 cm; the average height is 12-14 m and the maximal 16 m.

A shrubby tier is virtually absent. Individual suppressed shrubs are occasionally encountered in sol. abundance: *Rosa spinosissima, Caragana pumila, Spiraea hypericifolia,* and *Lonicera microphylla*.

The herbaceous cover is weakly developed (the projective cover does not exceed 5%) and poor in floristic composition. The indicator species, distinguished by a high constancy and close linkage with this association, is *Antennaria dioica* (sol.-sp.). In addition, the following species have relatively high constancy indicators: *Sedum hybridum, Polygonum convolvulus, Chenopodium album, Veronica incana, Asplenium septentrionale,* and *Polypodium vulgare* (sol.-sp.).

The mossy-lichen tier is strongly developed in regions untouched by recent ground fires, covering 60-80% of the soil surface with a distinct predominance of lichens. It is composed of the species: *Cladonia amaurocraea* (cop.$_1$-cop.$_2$), *C. alpestris*, *Peltigera malacea*, *Polytrichum juniperinum*, *Parmelia saxatilis*, and *Cladonia rangiferina* (sol.-sp.). At sites recently burned by running ground fires the abundance of the moss *P. juniperinum* is greatly increased, the lichen cover is nearly absent, and fallen pine needles are predominant on the soil surface, which provided certain foresters the basis for distinguishing here a special forest type, the "litter-covered pine forest." However, the lichen cover will be restored if the fires are not repeated during the next ten years.

Shrubby Pine with *Cotoneaster melanocarpa* and *Rosa spinosissima*. This association is encountered on slope trains and in small ravines enriched with the soil products of granite weathering. The soil is a brown mountain-forest humus—chernozem-like loam and forms on a diluvium of granite-weathering products. The fine-earth thickness is 50-60 (up to 80) cm. The soil layer almost completely covers the surface (up to 90-95%); granite-block outcrops are rare.

A_0 (0-3 cm). Litter consisting of decomposed needles, cones, and roots of herbaceous plants.

A_1 (3-12 cm). Dark-gray light loam with white gruss patches, cloddy—powdery. Up to 20% granite gruss and gravel and abundant tree, shrub, and herb roots.

AB (12-22 cm). Brownish dark-gray medium loam, cloddy, packed, 10% granite gruss mixture.

BC (22-60 cm). Brown medium loam with gray humus patches, indistinct fine-walnut loam, up to 10% gruss. No effervescence.

C (60 cm and deeper). Granite blocks.

The tree stand consists of pine with a negligible admixture of birch and aspen. The site class is III, crown density 50-70%, the mean pine diameter 20-28 cm and the maximal 64 cm, and the mean height 18-20 m and the maximal 22 m. The wood reserve is 170-250 m^3 per ha.

The shrubby tier is well developed and produces a dense thicket difficult to penetrate with 1-1.5 m average height and 2.5 m maximal height and a cover of 70-80%. The shrubbery consists of *Cotoneaster melanocarpa* and *Rosa spinosissima* (cop.$_2$-cop.$_3$), *Spiraea hypericifolia* and *Rosa laxa* (cop.$_1$), and *Ribes saxatile* (sol.). The herbaceous cover is dense (cover 60-80%) and rich in species composition. The mean herbage height is 0.6 m, the maximal 1 m. It is composed of *Filipendula hexapetala* and *Thalictrum foetidum* (cop.$_1$-cop.$_3$), *Fragaria viridis*, *Hieracium virosum*, *Libanotis sibirica*, and *Galium verum* (sol.-cop.$_2$), *Phlomis tuberosa* and *Achillea nobilis* (sol.-cop.$_1$), and others. Xeromesophilic forbs are predominant among the most abundant and constant components.

The moss—lichen cover is strongly developed (projective cover 60-80%) with predominance of the boreal green mosses *Pleurozium schreberi* (cop.$_1$-cop.$_2$), *Ptilium crista-castensis* (sol.-cop.$_2$) and *Hylocomium splendens* (sol.-cop.$_1$) with a negligible participation of the forest-steppe and steppe moss *Abietinella abietina* and an admixture of the lichens *Peltigera rufescens* (sol.-sp.), *P. canina* (sol.), and others.

ANTHROPOGENIC CHANGES IN THE VEGETATION.

DERIVATIVE PLANT COMMUNITIES

The forested area of Kazakhstan, as was well described by L. N. Gribanov (1957, 1965b), has declined markedly in historical time as a result of human activity. The nomadic tribes that populated this region inflicted definite harm on the trees during the several past millenia, using wood for their economic needs and setting fires to burn the steppe vegetation. Beginning with the first half of the 19th century, after the arrival of Russian settlers and the appearance of quarries, the depletion of the forests gained catastrophic proportions. Thus, the mountain office of the Altai Mountain District P. I. Shangii in 1816 determined the area of Bayanaul'skii Forest to be 1000 square versts, but after only 52 years, in 1868, an investigation conducted by lieutenant-colonel Krasovskii showed that only 250 square versts remained under forest (Gribanov, 1965b). By the beginning of 1980, according to forest-management data, the area covered by this forest comprised 173 km^2, of which 130 km^2 were beneath pine. Consequently, the area of the Bayanaul'skii Forest declined by approximately sixfold in 164 years.

The impact of man resulted in a greater breakup of the forests into separate isolated tracts, a considerable reduction in the area covered by forest, the appearance of treeless regions within forest tracts, and an increase in the area of sparse stands.

Steppe vegetation has been and remains a natural antagonist of pine communities in Central Kazakhstan. Human activity has been directed against the forest in favor of steppe communities. As a result, pine has been crowded out of a number of its former habitats.

Pine forests and sparse stands have been better preserved on exposed granite crags and on steep rocky slopes with a weakly developed, frequently rudimentary or fragmentary soil cover and an inadequate and unstable moisture supply to the surface soil layer, where the possibility of competition from herbaceous steppe vegetation is minimized. Pine rather successfully renews itself after cuttings and fires in such rocky habitats, since the sod grasses competing with pine shoots and seedlings do not find the conditions here favorable for their development. However, plant successions can be traced at sites subjected to especially severe anthropogenic impact.

Thus, craggy deserts with a ruderal vegetation have replaced the indigenous sparse pine stands on pillow platforms with *Dasiphora parviflora*, while derivative rocky sparse stands with *Chamaenerion angustifolium* and *Polygonum convolvulus* have replaced the rocky pine forests with *Sedum hybridum* and *Veronica incana*. We shall describe these communities.

Craggy Deserts with Ruderal Vegetation. These communities are encountered on remnant ridges with pillow granite platforms near recreational centers (for example, on the north shore of Dzhasybai Lake). The platform surface is bare, and the soil rudiments in gaps between platforms are solidly packed. The woody tier has been totally destroyed and the shrubby tier suppressed and represented by single stunted specimens of *Dasiphora parviflora*. The herbaceous tier contains few specimens of *Chenopodium album* and *Urtica dioica* (sol.-sp.) and others.

Rocky—Craggy Sparse Pine Stand with *Chamaenerion angustifolium* and *Polygonum convolvulus*. This community occupies steep (15-30°) slopes of southwestern, southern, southeastern, and eastern orientation. The surface is strongly eroded with rock outcrops, numerous large blocks (up to 3-4 m in diameter) and smaller granite fragments. A large part of the surface is bare. The soil is a mountain-forest, primitive-accumulative fragmentary (covering no more than 20% of the surface) loam and is developed only in gaps between granite blocks, where a small quantity of fine earth and gruss accumulate. The thickness of the fine-earth layer averages 10-15 cm and rarely reaches 25 cm.

A_0 (0-1 cm), Litter consisting of needles, pieces of bark, and pine cones.

A_1B (1-12 cm). Sandy loam of brown coloration with large gruss content, friable.

C (12 cm and deeper). Granite blocks.

The woody tier consists of pine with the sole admixture of *B. verrucosa*, it is sparse (crown density 0.2), and the site class is V-Va. The pine trees grow in depressions between blocks of rock, their mean diameter is 20 cm with a maximal of 32 cm, the mean height is 6 m with a maximal of 8 m, and the wood reserve is 40-70 m^3 per 1 ha.

The shrubby tier is almost unexpressed (projective cover less than 5%) and is represented by solitary specimens of *Spiraea hypericifolia* and *Caragana pumila* (sol.-sp.), and *Ribes saxatile* and *Juniperus sabina* (sol.).

The herbage is very weakly developed, and its cover does not exceed 5%. Herbaceous plants are encountered singly or in small groups of individuals at sites where a fine earth accumulates. This association is characterized by the synanthropic species: *Chamaenerion angustifolium* and *Polygonum convolvulus* (sp.). In addition, the following are distinguished by an elevated constancy: *Hieracium asiaticum*, *Euphorbia humilis*, *Chenopodium album*, *Libanotis baschtormensis*, *Veronica incana*, and *Asplenium septentrionale* (sol.-sp.) and *Sedum hybridum* (sol.).

The moss-lichen cover, occupying 20-30% of the substrate surface, consists of *Peltigera malacea* and *Parmelia saxatilis* (cop.$_1$-cop.$_2$), *Grimmia laevigata* (sol.-sp.), *Parmelia sulcata* and *Hedwigia ciliata* (sol.-sp.), and others.

Anthropogenic factors have had a considerably more negative impact on pine forests growing in intermountain basins, the depressions between rocky ridges, on gentle slopes, as well

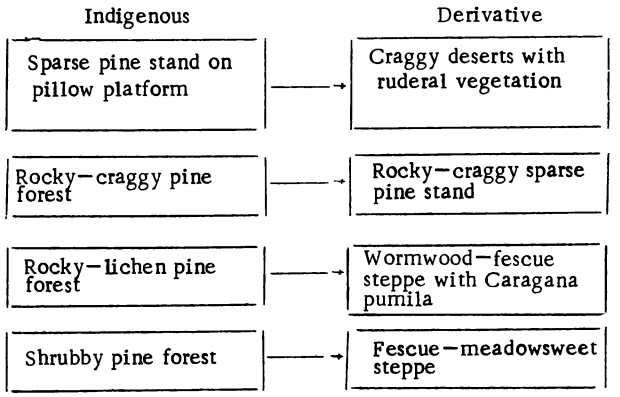

Fig. 2. Plant communities.

as on trains, where a considerable fine earth is accumulated, the soil is richer, and the moisture supply is more abundant and stable. Cuttings and burns in such areas are rapidly overgrown by steppe sod grasses, which create a barrier for the appearance of pine shoots and forest restoration. Repeated cuttings and burns as well as livestock grazing have resulted here in the replacement of rocky—lichen pine forest by a wormwood—fescue steppe with *Caragana pumila*, while shrubby pine forest has been replaced by a shrubby fescue—meadowsweet steppe.

Wormwood—Fescue Steppe with *Caragana pumila*. The soil is a shallow mountain chernozem, gruss—light-loam soil. The shrubby tier is produced by *Caragana pumila* (cop.$_1$), and the projective cover is 20-25%. The herbage is rather dense, with a cover of 60-70% and the principal components: *Festuca valesiaca* ssp. sulcata (cop.$_2$-cop.$_3$), *Artemisia austriaca* (cop.$_2$), *Phlomis tuberosa*, *Potentilla bifurca*, *Helictotrichon desertorum*, and *Orostachys spinosa* (sp.).

Fescue—Meadowsweet Steppe. The soil is a mountain light-loam chernozem. The shrubby tier is dense (cover 50-60%) and consists of *Spiraea hypericifolia* (cop.$_3$), *Rosa spinosissima* (cop.$_1$), and *Cotoneaster melanocarpa* (sp.). The herbage is of moderate density (40-50%) and consists of *Festuca valesiaca* ssp. sulcate (cop.$_2$), *Filipendula vulgaris* and *Phlomis tuberosa* (sp.-cop.$_1$), *Phleum phleodies*, *Onosma simplicissimum*, *Galium verum*, and *Carex supina* (sp.) and others.

The scheme in Fig. 2 shows the main trends in the anthropogenic successions of pine forests and arid-petrophytic sparse stands in granite foothills of the dry fescue—feather grass steppe subzone of Central Kazakhstan. As is apparent, the anthropogenic degradation of the vegetation results in an increasing aforestation, in the replacement of sparse pine stands by deserts, and in the replacement of pine forests by sparse stands and wormwood—fescue and shrubby steppes.

CHARACTERISTICS OF ARID-PETROPHYTIC SPARSE PINE STANDS

Arid-petrophytic sparse pine stands are a unique botanogeographic phenomenon, characteristic of the peripheral, most arid and continental portion of the common-pine distribution range. They are formed under azonal conditions, within the steppe zone of Central Kazakhstan, and in the most eroded portions of the sharply dissected granite foothills. Soil formation at such sites is in the initial stages, since most of the fine-earth products of weathering are carried off down the slopes. Only a negligible portion of the fine earth accumulates on the flat surfaces of granite blocks, in depressions, and in gaps. No more than 10-20% of the surface is occupied by such soil rudiments. In spite of the overall aridity of the substrate and its poverty in both humus and mineral nutrients, in the gaps in rocks where fine earth is accumulated relatively favorable conditions are created for the appearance of sprouts and the development of seedlings and later even adult trees, whose roots penetrate through the cracks to a considerable depth. Fine earth is unevently distributed in sparse stands, which accounts for the mosaic quality of the habitats. Only a very small portion of the weathered-granite surface (at sites of fine-earth accumulation) is favorable for the establishment and growth of pine. Therefore, dense pine communities cannot develop here, and only sparse stands are produced. The woody tier is very thin (projective cover 5-15%, no more than 20%). Here

pine loses the leading environment-producing role of an edificator, and the phytoclimate of sparse stands approximates the phytoclimate of open treeless spaces. The pine trees are short (3-6 m, maximum 8 m), their trunks are severely tapered and often monstrously bent. The shrubby tier is virtually absent. The herbaceous cover is weakly developed and lacks forest plants, while petrophytes and forest-steppe and steppe mesoxerophytes predominate. The moss—lichen cover is represented primarily by epilithic lichens and partially by mosses.

The seed productivity of pine in sparse stands is rather high (288 ± 66 cones per single tree; Tokarev, 1969), which is a result of good crown illumination. The seed crops are stable, and cropless years are rare. However, a large portion of the new pine shoots perish. Self-seeding is only reliable when an increased amount of rain falls in June and July for no less than three summers running. As Tokarev notes, such favorable meteorological conditions do not often occur. Natural renewal is characterized by cyclicity, and bursts of renewal alternate with periods of complete quiescence. The tree stands thus have a cyclicly mixed age structure.

Derivative, or secondary sparse stands are found in Central Kazakhstan along with indigenous or primary stands. Derivative stands replaced forests with a dense woody tier and a developed soil covering no less than 50% of the surface of a craggy substrate. The current sparseness of the tree stands is a result of human activity (cuttings, fires, trampling). The decline in stand density resulting from anthropogenic impact leads to an increase in hydrologic soil errosion, irreversibly changing the soil cover (the soil is fragmentary, covering less than 20% of the craggy substrate). The bareness of the greater portion of the surface in conjunction with severe erosion limits the possibility of the appearance of an adequately abundant undergrowth and excludes the natural restoration of more or less dense stands for the foreseable future. Synanthropic species have a large role in the herbaceous cover of derivative sparse stands.

CONCLUSIONS

1. Isolated tracts of common-pine communities associated with granite foothills are encountered in the steppe zone of Central Kazakhstan. With respect to their character, these communities are subdivided into two large groups: forests with a more or less dense woody tier and arid-petrophytic sparse stands.

2. The extrazonal position of pine communities in Central Kazakhstan, the rockiness of the substrate, and the attenuation or complete loss of the environment-producing role of the woody tier determines the specific characteristics of the herbaceous floristic composition. The herbage is dominated by petrophytes and steppe and forest-steppe species, boreal species are absent or are encountered sporadically, assuming here the position of relics, and the role of synanthropic species is greater or smaller depending upon the degree of anthropogenic degradation of the communities.

3. Many pine communities in granite foothills are characterized by a fragmentary, shallow soil in the early stages of formation, a large portion of the surface is bare, and the herbaceous cover is usually weakly developed without clear dominance of any single species. Thus, it is usually impossible to subdivide such communities into associations according to dominant species. Pine communities at the southern limit of their distribution may be successfully classified on the basis of indicator species characteristic of one or another association and of specific environmental conditions and which are distinguished by a high constancy.

4. In the southern steppe zone, in the dry feather grass—fescue steppe subzone, indigenous communities with pine in the woody tier are represented by the following principal associations: sparse pine forest on pillow platforms with *Dasiphora parviflora*, rocky—craggy pine forests with *Sedum hybridum* and *Veronica incana*, rocky—lichen pine forest with *Antennaria dioica*, and shrubby pine forest with *Cotoneaster melanocarpa* and *Rosa spinosissima*.

5. In the course of anthropogenic degradation the primary sparse pine stands on pillow platforms are replaced by craggy deserts with a ruderal vegetation; the rocky—craggy pine forest is replaced by a sparse stand with the synanthropic species *Chamaenarion angustifolium* and *Polygonum convolvulus*; the rocky—lichen pine forest is replaced by a wormwood—fescue steppe with *Caragana pumila*; the shrubby—fescue—lichen pine forest is replaced by a wormwood—fescue steppe with *Caragana pumila*; and the shrubby pine forest by fescue—meadowsweet steppe.

6. Highly unique arid petrophytic sparse stands are developed on the most arid and continental portion of the common pine distribution range in strongly eoroded granite foothills. These stands are characterized by a rudimentary soil that is not divided into horizons and with fine-earth accumulations in gaps between rocks, the woody tier is very sparse (projective cover 5-15, rarely up to 20%), the trees are short with distorted trunks, the shrubby tier is suppressed, the herbaceous tier weakly developed with a predominance of petrophytes, and epilithic lichens and mosses are abundant. Derivative sparse stands, replacing the relatively dense forests as a result of degradation, are encountered along with indigenous stands. Synanthropic species are the indicator species in derivative sparse stands.

LITERATURE CITED

Alisov, B. P., Climate of the USSR [in Russian], Izd. MGU (1956).

Fedorovich, B. A., "Geomorphological regionalization," in: Kazakhstan [in Russian], Nauka, Moscow (1969).

Gorchakskii, P. L. and Lalayan, N. T., "Relic black alder forests in the Kazakh Hill Country and their alteration by human activity," Ékologiya, No. 4, 19-31 (1981).

Gordyagin, A. Ya., "The Kokchetavskii Forests," Zap. Zap.-Sibirsk. Otd. Russk. Geogr. Obshch., 22, 1-18 (1897).

Gribanov, L. N., "History of steppe forests in Western Siberia and Northern Kazakhstan," Bot. Zh., No. 4, 556-570 (1957).

Gribanov, L. N., Kazakhstan Pine Forests and the Biological Bases of Their Management [in Russian], Inst. Biol. Ural. Fil. Akad. Nauk SSSR, Sverdlovsk (1965a).

Gribanov, L. N., "Change in the southern limit of pine in Kazakhstan," Vestn. Skh. Nauki, No. 6, 77-86 (1965b).

Gvozdetskii, N. A., and Nikolaev, V. A., Kazakhstan [in Russian], Mysl', Moscow (1971).

Handbook on the Climate of the USSR [in Russian], Vol. 18, Kazakh SSR, Gidrometeoizdat, Leningrad; No. 2, Air and Soil Temperature (1966), 656 pp.; No. 4, Atmospheric Moisture, Precipitation, and Snow Cover (1968).

Karamysheva, Z. V., "Vegetation of northeastern portion of Central Kazakhstan Hill Country in Pavlodar Oblast," Tr. Bot. Inst. Akad. Nauk SSSR, Ser. 3 (Geobotanika), 13, 464-486 (1961).

Soil Map of Kazakh SSR. Scale 1:2,500,000 [in Russian], U. U. Uspanov, ed., Izd. GUGK, Moscow (1976).

Sukachev, V. N., "Outline of forest vegetation in Borovoe Reserve," Tr. Zapoved. Borovoe, 1, 14-40 (1948).

Tokarev, A. D., "Sparse pine stands in Bayano-Karkaralinsk Foothills and characteristics of their renewal," Author's Abstract of Candidate's Dissertation, Kazakh Agricultural Inst., Alma-Ata (1969).

Vegetation Map of Kazakh Hill-Country Steppe [in Russian], E. M. Lavrenko, ed., Izd. GUGK, Moscow (1975).