Technical Report No. 70

DRAWINGS OF TISSUES OF PLANTS FOUND IN HERBIVORE DIETS AND IN THE LITTER OF GRASSLANDS[1/]

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1/ This is a new report and a revision of Technical Report No. 18 by Cavender and Hansen.

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ABSTRACT

This report supersedes Technical Report No. 18 and describes in greater detail the microscope technique used in the identification of plant fragments. This report explains how percentage density is converted to relative percentage density. It shows how to estimate the percentage dry weight of each species of plant in herbivore diets, litter, mulch, and other complex plant species mixtures using the microscope technique. The complete report also consists of drawings of plant fragments commonly found in the samples that have been processed in the Grasslands Ecology Research Laboratory.

IDENTIFICATION AND QUANTIFICATION OF PLANT FRAGMENTS

The "microtechniques" method is the most accurate for identifying plant material taken from the stomachs of herbivores. This technique was described by Baumgartner and Martin (1939), and the technique was later defined by Dusi (1949). This basic technique has been used in recent years in many studies of the diets of herbivores (Mulkern and Anderson 1959; Ward 1960; Ward and Keith 1962; Myers and Vaughan 1964; Bear and Hansen 1966; Hayden 1966; Malechek 1966; Vaughan 1967; Sparks 1968; and Ueckert 1968). A brief discussion of this valuable technique seems appropriate.

Tissues of leaves, stems, and flowers, etc., are collected from all plants occurring on the range of the animal whose dietary habits are to be studied. These tissues are partially ground and mounted on glass microscope slides. These slides serve as a reference collection to aid in the identification of material taken from stomachs. The contents of a herbivore's stomach is dried and then ground in a Wiley laboratory mill, usually over a 1 mm screen, to reduce all fragments of plants to a uniform size. Samples are washed over a 200 mesh screen to remove dirt and small fragments of plants. The washed samples from the stomachs, either stained or unstained, are spread evenly and mounted on microscope slides, using Hertwig's solution and Hoyer's solution (Bear and Hansen 1966) or Permount (Hayden 1966). The slides may then be dried in an oven at 60°C for 3 days.

The identification of each plant species, by microscopic techniques, is based on characteristics of epidermal tissues (Davis 1959; Croker 1959; Brusven and Mulkern 1960; Storr 1961). Usually 10 to 80 locations are observed, at 40 to 125 power magnification, on 1 to 5 slides prepared from

the contents of 1 animal's stomach. A location is considered as an area of the slide delimited by a field of the microscope at a selected power of magnification. Only those fragments that are recognized as epidermal tissue (other than hair-like structures) are recorded as postivie evidence for the presence of a plant species at a location on the slide. Data taken from readings of slides are either expressed as percent of frequency of each species or as percent composition of each species. The percent of frequency (number of locations that the species occurred in out of 100 locations) is most easily and accurately taken for plant species in the sample. Percent of frequency may be converted to density of particles per location using a table (Table 1) developed by Fracker and Brischle (1944).

The relationship of frequency to density is expressed in the formula $F = 100(1 - e^{-D})$, and the mechanics of the conversion can be seen by using a sample problem as follows:

> If 20 locations were examined on each of 50 slides made from the contents of stomachs of 50 herbivores, taken in the same study area, the conversion of frequency to density is as follows: 50 slides × 20 locations = 1,000 total locations. If plant species A occurred in 700 of these locations the percent of frequency would be:
>
> $$F = \frac{\text{no. of locations in which species A occurs}}{\text{total no. of locations examined}} \times 100$$
>
> $$= \frac{700}{1000} \times 100$$
>
> $$= 70\%$$
>
> Converting F to mean density/1000 locations, we have:

Table 1. Relations of frequency to density and abundance (for strictly random distributions).

Freq. %	Den. Q	Abun. Q	Freq. %	Den. Q	Abun. Q
1	0.01	1.01	52	0.73	1.41
2	0.02	1.01	53	0.75	1.42
3	0.03	1.02	54	0.77	1.44
4	0.04	1.02	55	0.80	1.45
5	0.05	1.03	56	0.82	1.47
6	0.06	1.03	57	0.84	1.48
7	0.07	1.04	58	0.86	1.49
8	0.08	1.04	59	0.89	1.51
9	0.09	1.05	60	0.91	1.53
10	0.10	1.05	61	0.94	1.54
11	0.11	1.06	62	0.96	1.56
12	0.12	1.06	63	0.99	1.58
13	0.14	1.07	64	1.02	1.60
14	0.15	1.08	65	1.05	1.61
15	0.16	1.08	66	1.08	1.63
16	0.17	1.09	67	1.11	1.65
17	0.18	1.10	68	1.14	1.67
18	0.20	1.10	69	1.17	1.70
19	0.21	1.11	70	1.20	1.72
20	0.22	1.12	71	1.23	1.74
21	0.23	1.12	72	1.27	1.77
22	0.25	1.13	73	1.31	1.80
23	0.26	1.14	74	1.35	1.82
24	0.27	1.14	75	1.39	1.85
25	0.29	1.15	76	1.43	1.88
26	0.30	1.16	77	1.47	1.91
27	0.31	1.17	78	1.51	1.94
28	0.33	1.17	79	1.56	1.98
29	0.34	1.18	80	1.61	2.01
30	0.35	1.19	81	1.66	2.05
31	0.37	1.20	82	1.71	2.09
32	0.38	1.20	83	1.77	2.14
33	0.40	1.21	84	1.83	2.18
34	0.41	1.22	85	1.89	2.23
35	0.43	1.23	86	1.96	2.28
36	0.44	1.24	87	2.04	2.34
37	0.46	1.25	88	2.12	2.41
38	0.48	1.26	89	2.20	2.48
39	0.49	1.27	90	2.30	2.56
40	0.51	1.28	91	2.40	2.64
41	0.52	1.29	92	2.52	2.75
42	0.54	1.30	93	2.66	2.86
43	0.56	1.31	94	2.81	2.99
44	0.58	1.32	95	2.99	3.15
45	0.60	1.33	96	3.22	3.35
46	0.62	1.34	97	3.51	3.62
47	0.63	1.35	98	3.91	3.99
48	0.65	1.36	99	4.60	4.65
49	0.67	1.37	99.5	5.30	5.32
50	0.69	1.38	99.9	6.91	6.91
51	0.71	1.40	100	--	--

$$70 = 100(1 - e^{-D})$$

$$\frac{70}{100} = (1 - e^{-D})$$

$$0.7 = 1 - e^{-D}$$

$$0.7 - 1.0 = -e^{-D}$$

$$-(-0.3) = -(-e^{-D})$$

$$0.3 = e^{-D}$$

Now, to find the value of D we look up the X value of $e^{-X} = 0.3$ in a standard mathematical table of "Values of Exponential Functions," and we see that D (or X) equals 1.20. With a frequency of 70%, we have a mean density of 1.20 particles of species A per location, D = 1.20.

There are two requirements that must be met before percent of frequency can be converted to density (Curtis and McIntosh 1950). The fragments of plants must be distributed randomly over the slide, and the density of particles must be such that the most common species does not occur in more than 86% of the fields of the microscope. Thorough mixing of material and adjustments of the quantity placed on the slides will take care of both these requirements.

Recent technological advances (Sparks and Malechek 1968) have added another dimension to the microscopic technique. Density of particles per location is converted to relative density:

$$\left(\frac{\text{Density of particles of species A}}{\text{Total density of particles of all species}} \times 100\right).$$

The relative density of a species is then used to estimate percent of dry weight of that species in the mixture. Equations of regression that express the relationship between estimated percent of dry weight (X) and actual percent of dry weight (Y) were developed for three categories of plants: grasses, forbs, and grass-forb combinations. The ratio between estimated percent of dry weight (relative density) and actual percent of dry weight was approximately 1:1 for all three categories. Student's (t) test showed there was no significant difference between the equations of regression for grasses and forbs, and that the calculated equations of regression for grasses, forbs, and grass-forb combinations were not statistically different from the equation $Y = X$. Therefore, the percent of dry weight of a mixture can be predicted directly from the relative density.

Storr (1961) and Heady and Van Dyne (1965) reported that specific gravity (weight per unit area) of plant material is not consistent at different stages of maturity nor is it consistent from species to species. The 1:1 relationship between estimated percent of dry weight and actual percent of dry weight may not be consistent with all species or at all stages of maturity. However, unless the parts of plants in the diet being analyzed are grossly different from those reported by Sparks and Malechek (1968), the added accuracy gained by using an equation of prediction more complicated than $Y = X$ would probably not be worthwhile.

Estimating Dry Weight

Dry weight percentages for each species in a mixture can be computed from "counting particles" or by "converting frequency to density" with a similar degree of accuracy, but it is much less work to use the "frequency conversion" technique (Sparks and Malechek 1968). In IBP work, we use the "frequency conversion" technique. The estimates of dry weight depend on the recognition of fragments of species (or genera) of plants, and since the technique does estimate percentage dry weight, the non-descriptive fragments of a species and the recognizable fragments on a microscope slide must have about a 1:1 ratio.

Percentage frequency is equal to the number of microscope fields in which a plant species is recognized, divided by the total number of microscope fields examined (a sample) times 100. Density is the number of individually recognized fragments of a species of plant found per microscope field. Density may be expressed as a percentage value. Percentage density is found by dividing the mean number of recognized fragments of a plant species by the number of recognized fragments found of all different species of plants times 100. Percentage density is, thus, totally independent of area, at least in its method of calculation, and is actually a relative term and is best called "relative density."

The percentage frequency of recognized fragments of plants in a sample can be converted to density of fragments per microscope field using a table developed by Fracker and Brischle (1944) or the density per microscope field may be calculated using a formula. The most suitable microscope slide for converting frequency to density for the most common item in the sample is a

slide with a fragment density that results in a mean frequency around 63% for the species of plant with the greatest number of individual fragments. All other species in the sample would have lesser frequencies. The optimum use of relative frequency is when the recognizable fragment density on slides is adjusted so the frequency of the most numerous item is about 86%. A practical compromise is to add enough of the sample to each microscope slide so that three to six recognizable fragments occur in each microscope field.

Expected and Observed Frequencies

The frequencies of recognized fragments of plants in relation to their known relative dry weights fit a binomial distribution. If the expected frequency of a species of plant is compared to its observed frequency in 10 samples examined by observing different sample unit sizes (=SUS) as follows:

Sample Unit Size (SUS)	No. of Samples	No. of Slides/sample	No. of Fields/sample	Total No. Fields
20 fields/sample	10	5	20	1000
40 fields/sample	10	4	20	800
60 fields/sample	10	3	20	600
80 fields/sample	10	4	20	800
100 fields/sample	10	5	20	1000

The expected and observed frequencies for plant species are very similar. If the sample unit size (=SUS) is 20 fields/sample, one would not expect (due to chance) an item making up 0.5% dry weight of the sample to be detected on 4 of 5 slides (20 fields/slide). If the SUS is 60 fields, one could expect

the mean frequency of the same item to be about 70%. Likewise, as the mean percentage dry weight (= category size) increases within any SUS, the chances increase for detecting more fragments from a large category size in a microscope field. In some hand-compounded samples, the frequency of items making up 15% of each sample's composition is always 100% at all SUS levels and items making up about 2% of the dry weight always have 100% frequency when the SUS level is 60 or more. If microscope slides are made so three to six recognizable fragments occur in each microscope field, there will be from about 60 to 120 chances for "recognition scores" per SUS-20, or about 300 to 600 recognizable fragments per SUS-100. The chances of recording fragments for each species of plant in a diet will depend on the numbers of species and the amounts of each in a sample.

Slide Preparation Materials

Microscope slides . . . . glass, plain, standard size, laboratory grade

Cover slips . . . . . glass, 22 × 40 mm for most animals

glass, 22 × 22 mm for insects

Slide labels

Plastic squeeze bottles with spout (2)

Teasing needles (2)

Spatula with narrow, flexible blade

Sponge

200 mesh screen

Drying oven and racks

Waring blender (1 quart)

Hertwig's solution--clearing agent

240 g chloral hydrate crystals

19 cc 1N HCl

60 cc glycerin

Combine glycerin and HCl, add chloral hydrate crystals, stir until crystals dissolve. The crystals will dissolve faster if the mixture is warmed and agitated in a blender.

Hoyer's solution--mounting medium

200 g chloral hydrate crystals

50 cc water

20 cc glycerin

30 g photo purified gum arabic

Combine glycerin and water, add chloral hydrate crystals, stir until crystals dissolve. Warm the solution and stir in gum arabic. The mixture may be agitated with a blender after the gum aribic is added. Let stand until the solution clears.

Method for Handling Samples

In the field, samples intended only for diet studies can be frozen, air dried, or preserved in alcohol. Samples intended for energy determinations or chemical analyses, as well as diet study, should be air dried, oven dried (below 70°C), or frozen as soon as possible and should not be placed in a preservative. Dietary samples from large herbivores (all stomach, fistula, rumen, or fecal material) should be air dried and then ground in a Wiley laboratory mill through a 1 mm (20 mesh) screen before microscope slides are

made. Mammals that weigh less than 200 g live weight usually chew their food fine enough so grinding is not necessary. Samples ground through a screen smaller than 20 mesh (1 mm) are not satisfactory for making slides. Samples removed from insect crops cannot be ground because of the small quantities involved. Dietary material from these small animals is transferred directly to slides without drying or washing.

Two slides should be prepared from each sample, if possible. Plant fragments should be spread evenly over the slide and should not overlap. At 100 power magnification, there should be about three large fragments per field.

Place approximately 10 cc of a ground or blended sample in a 0.1 mm (200 mesh) screen and wash under running water for one minute (Fig. 2). Remove a small amount of the washed material from the screen with a spatula, and spread near one end of a microscope slide (Fig. 3). Add three or four drops of Hertwig's solution to the wet material on the slide, then carefully boil off most of the Hertwig's by holding the slide above a small alcohol burner (Fig. 4). It is important, at this point, not to char the sample by overheating.

When most of the Hertwig's has boiled off, add enough Hoyer's solution to cover an area about 2/3 as large as a cover slip. With a teasing needle, mix the plant material with the Hoyer's and spread evenly over an area as large as a cover slip (Fig. 5). Place a cover slip on the preparation and heat the slide over the burner until the Hoyer's starts to boil. Immediately wipe the bottom surface of the slide with a cold, damp cloth or sponge to draw air bubbles out of the Hoyer's solution. Press a teasing needle gently on top of the cover slip to squeeze out excess mounting medium and remove any remaining

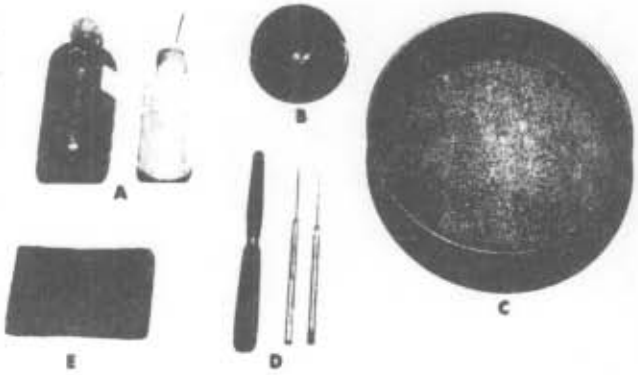

Figure 1. Materials needed: (A) plastic squeeze bottles, (B) alcohol burner, (C) 0.1 mm mesh screen, (D) teasing needles and spatula, (E) sponge.

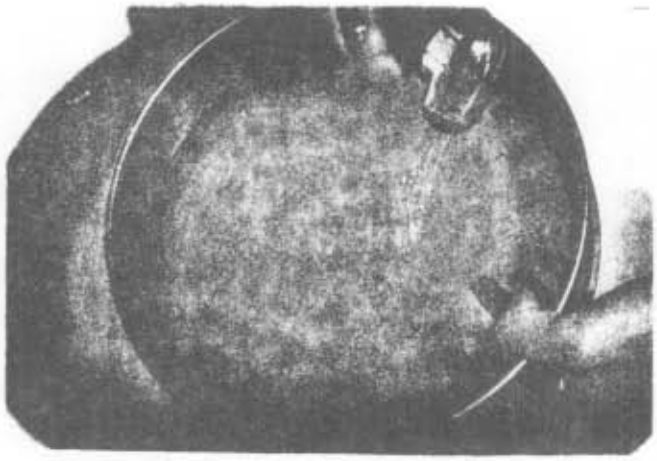

Figure 2. The ground sample is washed with water to remove dirt and small plant fragments over a 0.1 mm (200 mesh) screen.

Figure 3. A small amount of the sample is placed on a slide. About 3 or 4 identifiable particles per field is the desired density.

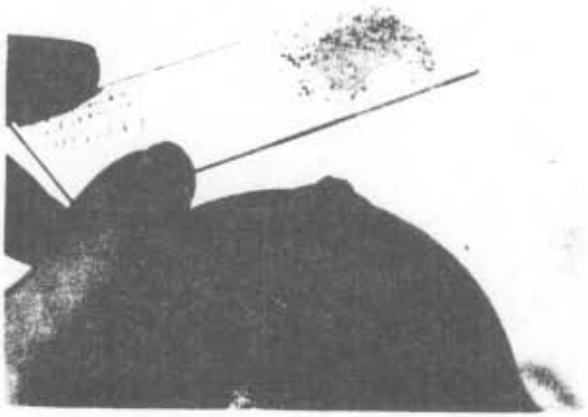

Figure 4. Hertwig's solution is boiled off over an alcohol burner.

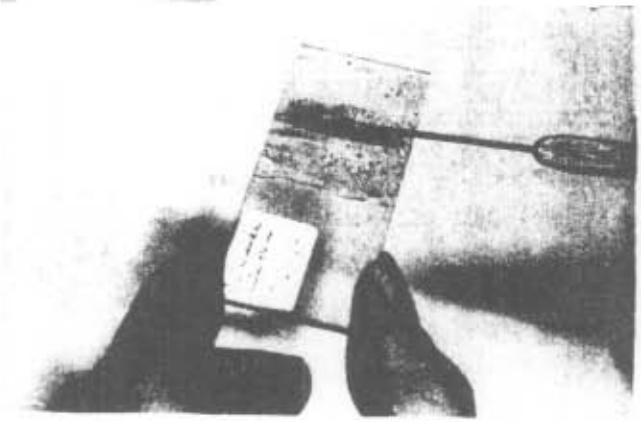

Figure 5. Hoyer's solution is mixed with the sample and spread evenly over the slide.

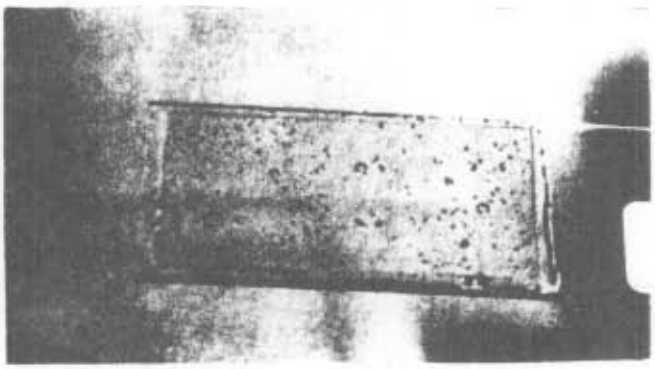

Figure 6. A finished slide showing the desirable approximate density of plant fragments and ring of Hoyer's around the cover slip. The air bubbles may be pressed out with a teasing needle while the slide is cooling after being heated.

air bubbles. (Very tiny bubbles usually disappear during the drying process and are not detrimental.) Apply a thin ring of Hoyer's solution around the edge of the cover slip, if needed, to form a seal as the slide dries.

Slides are placed flat on racks in a drying oven at 55°C for two to three days, or until the Hoyer's solution has hardened, then stored in a dry place. Hoyer's solution forms a permanent mounting medium when hardened, but is soluble in water allowing easy cleaning or reuse of slides.

Reference Slides

A collection of all species of plants present at a site should be available for making reference slides. The appropriate slides of leaf, stem, root, flower, and seed should be prepared for each species. The separate parts of each plant are placed in a Waring blender with enough water to at least cover the blades. Less than a teaspoon of plant material is needed, and plants may be green or dried.

After one to two minutes at high speed, the contents of the blender are poured into a 0.1 mm mesh screen and washed. Reference slides are made directly from this material, following the same procedure as for dietary samples, but applying more material to the slides.

Woody material may be ground in a Wiley mill before being added to the blender. Very hot water also helps soften tissue and removes plant pigments.

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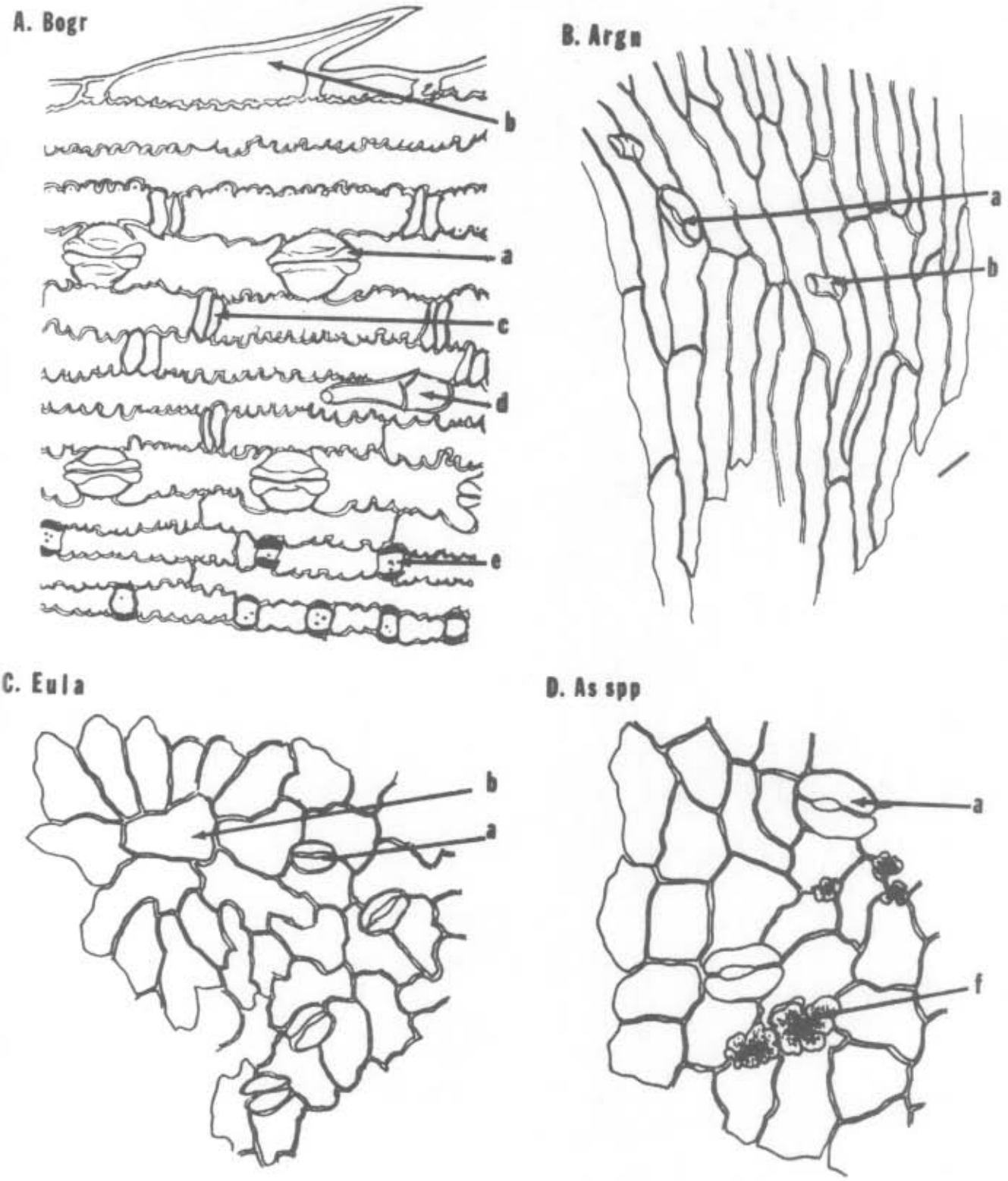
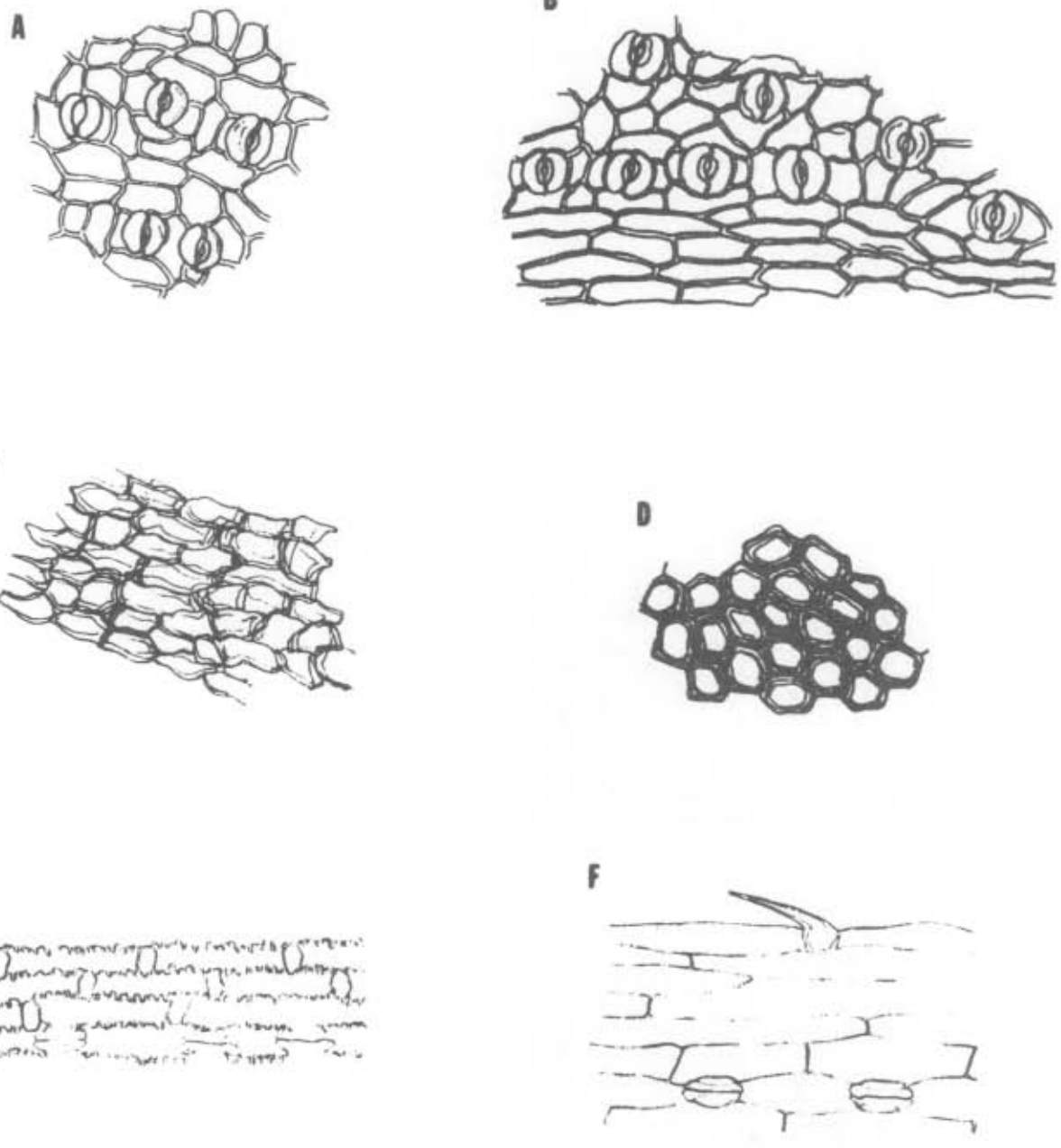
Table 2. Alphabetical list of symbols and plant names used for classifying the drawings of plant tissues in this technical report.

Symbol	Name of Plant Tissue	Symbol	Name of Plant Tissue	Symbol	Name of Plant Tissue
ABFR	*Abronia fragrans*	ERFL	*Erigeron flagellaris*	ORLU	*Orthocarpus luteus*
ACLA	*Achillea lanulosa*	ERSI	*Erigeron simplex*	ORHY	*Oryzopsis hymenoides*
AGPA	*Agoseris parviflora*	EREF	*Eriogonum effusum*	OXLA	*Oxytropis lambertii*
AGCR	*Agropyron cristatum*	ERAS	*Erysimum asperum*	OXSE	*Oxytropis sericea*
AGSM	*Agropyron smithii*	EUGL	*Euphorbia glyptosperma*	PEALB	*Penstemon albidus*
AL SPP	*Allium* spp.	EULA	*Eurotia lanata*	PEALP	*Penstemon alpinus*
ALTE	*Allium textile*	EVNU	*Evolvulus nuttallianus*	PERY	*Penstemon rydbergii*
AMRE	*Amaranthus retroflexus*	FEOC	*Festuca octoflora*	PHLA	*Physalis lanceolata*
AMEL	*Ambrosia elatior*	FRDI	*Franseria discolor*	PLPU	*Plantago purshii*
AMPS	*Ambrosia psilostachya*	GAAR	*Gaillardia aristata*	POPR	*Poa pratensis*
ANHA	*Andropogon hallii*	GABO	*Galium boreale*	POAV	*Polygonum aviculare*
ANSE	*Androsace septentrionalis*	GACO	*Gaura coccinea*	POBI	*Polygonum bistortoides*
ARFE	*Arenaria fendleri*	GEFR	*Geranium fremontii*	POCO	*Potentilla concinna*
ARIN	*Argemone intermedia*	GECI	*Geum ciliatum*	POFR	*Potentilla fruticosa*
ARLO	*Aristida longiseta*	GIAG	*Gilia aggregata*	POGL	*Potentilla glandulosa*
ARFI	*Artemisia filifolia*	GILA	*Gilia laxiflora*	POPE	*Potentilla pennsylvanica*
ARFR	*Artemisia frigida*	GLLE	*Glycyrrhiza lepidota*	POPU	*Potentilla pulcherrima*
ARGN	*Artemisia gnaphyloides*	GNCH	*Gnaphalium chilense*	PSTE	*Psoralea tenuiflora*
ARLU	*Artemisia ludoviciana*	GRSU	*Grindelia subalpina*	RACO	*Ratibida columnaris*
ASPU	*Asclepias pumila*	GUSA	*Gutierrezia sarothrae*	SAKA	*Salsola kali*
ASCO	*Aster coloradoensis*	HAFL	*Hackelia floribunda*	SARE	*Salvia reflexa*
AS SPP	*Aster* spp.	HASP	*Haplopappus spinulosus*	SCBR	*Scutellaria brittonii*
ASTA	*Aster tanacetifolius*	HEAN	*Helianthus annuus*	SEMU	*Senecio multicapitatus*
ASGR	*Astragalus gracilis*	HEPE	*Helianthus petiolaris*	SEIT	*Setaria italica*
ASPE	*Astragalus pectinatus*	HEPA	*Heuchera parvifolia*	SINE	*Sidalcea neomexicana*
AS SPP	*Astragalus* spp.	IVAX	*Iva axillaris*	SORO	*Solanum rostratum*
ATCA	*Atriplex canescens*	JU SPP	*Juncus* spp.	SOTR	*Solanum triflorum*
BAOP	*Bahia oppositifolia*	KOSC	*Kochia scoparia*	SOMI	*Solidago missouriensis*
BOGR	*Bouteloua gracilis*	KOCR	*Koeleria cristata*	SORI	*Solidago rigida*
BRIN	*Bromus inermis*	LASC	*Lactuca scariola*	SOSE	*Sophora sericea*
BUDA	*Buchloe dactyloides*	LARE	*Lappula redowskii*	SPCO	*Sphaeralcea coccinea*
CAGU	*Calochortus gunnisonii*	LALE	*Lathyrus leucanthus*	SPCR	*Sporobolus cryptandrus*
CARO	*Campanula rotundifolia*	LAPO	*Lathyrus polymorphus*	STPA	*Stephanomeria pauciflora*
CAHE	*Carex heliophila*	LEDE	*Lepidium densiflorum*	STCO	*Stipa comata*
CAIN	*Castilleja integra*	LEPU	*Leptodactylon pungens*	THAR	*Thlaspi arvense*
CASE	*Castilleja septentrionalis*	LELU	*Lesquerella ludoviciana*	THTR	*Thelesperma trifidum*
CHAL	*Chenopodium album*	LESMO	*Lesquerella montanum*	THDI	*Thermopsis divaricarpa*
CHVI	*Chrysopsis villosa*	LEUMO	*Leucocrinum montanum*	TOGR	*Townsendia grandiflora*
CHNA	*Chrysothamnus nauseosus*	LIPU	*Liatris punctata*	TROC	*Tradescantia occidentalis*
CIUN	*Cirsium undulatum*	LUAR	*Lupinus argenteus*	TRPR	*Tragopogon pratensis*
CLSE	*Cleome serrulata*	LUSP	*Luzula spicata*	TRDA	*Trifolium dasyphyllum*
COPA	*Comandra pallida*	LYJU	*Lygodesmia juncea*	VAED	*Valeriana edulis*
COCA	*Conyza canadensis*	MAVI	*Mammillaria vivipara*	VEBR	*Verbena bracteata*
CRFE	*Cryptantha fendleri*	MAVU	*Marrubium vulgare*	VI SPP	*Vicia* spp.
DE SPP	*Delphinium* spp.	MESA	*Medicago sativa*	VICA	*Viola canadensis*
DEPI	*Descurainia pinnata*	MEDE	*Mentzelia decapteala*	VINU	*Viola nuttallii*
DYPA	*Dyssodia papposa*	MILI	*Mirabilis linearis*	WYAR	*Wyethia arizonica*
ELCA	*Elymus canadensis*	MUDI	*Musineon divaricatum*	XASP	*Xanthium speciosum*
EQKA	*Equisetum kansanum*	NOCU	*Nothocalais cuspidata*	YUGL	*Yucca glauca*
ERBE	*Erigeron bellidiastrum*	OECO	*Oenothera coronopifolia*	ZYEL	*Zygadenus elegans*
ERCA	*Erigeron canadensis*	OPPO	*Opuntia polyacantha*		

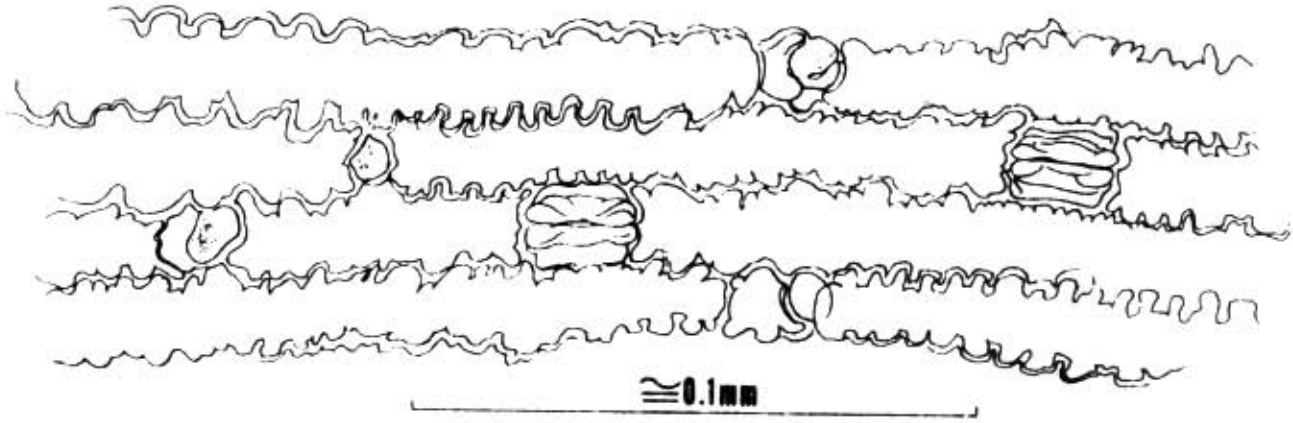


Comparison of four plants. A. Grass; orderly arrangement of cells; a, stomate; b, trichome; c, silica - suberose cell; d, asperite; e, silica cell. B. Shrub; random cell arrangement; a, stomate; b, trichome attachment. C and D. Forbs; random cell arrangement; a, stomate; b, trichome attachment; f, druce.

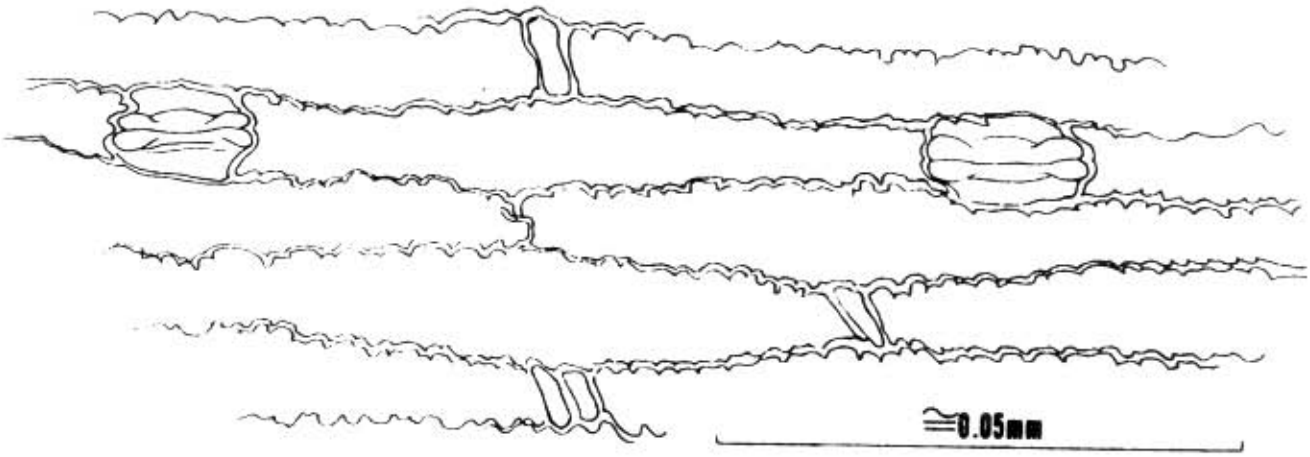


Comparison of epidermal cells in different parts of the plant: a. LYJU - leaf, near margin; b. LYJU - leaf, near vein; c. ARFR - stem; d. MAVI - seed coat; e. AGCR - upper side of grass blade; f. AGCR - lower side of grass blade.

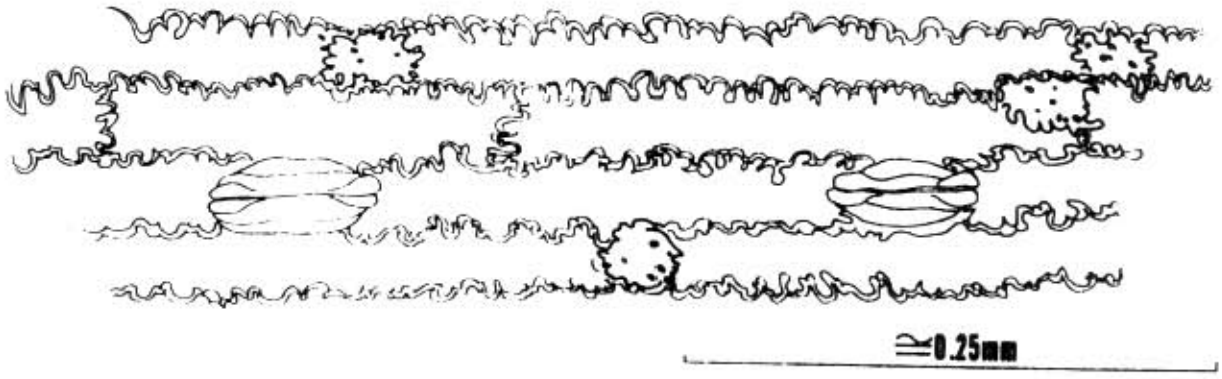
Feoc



Popr

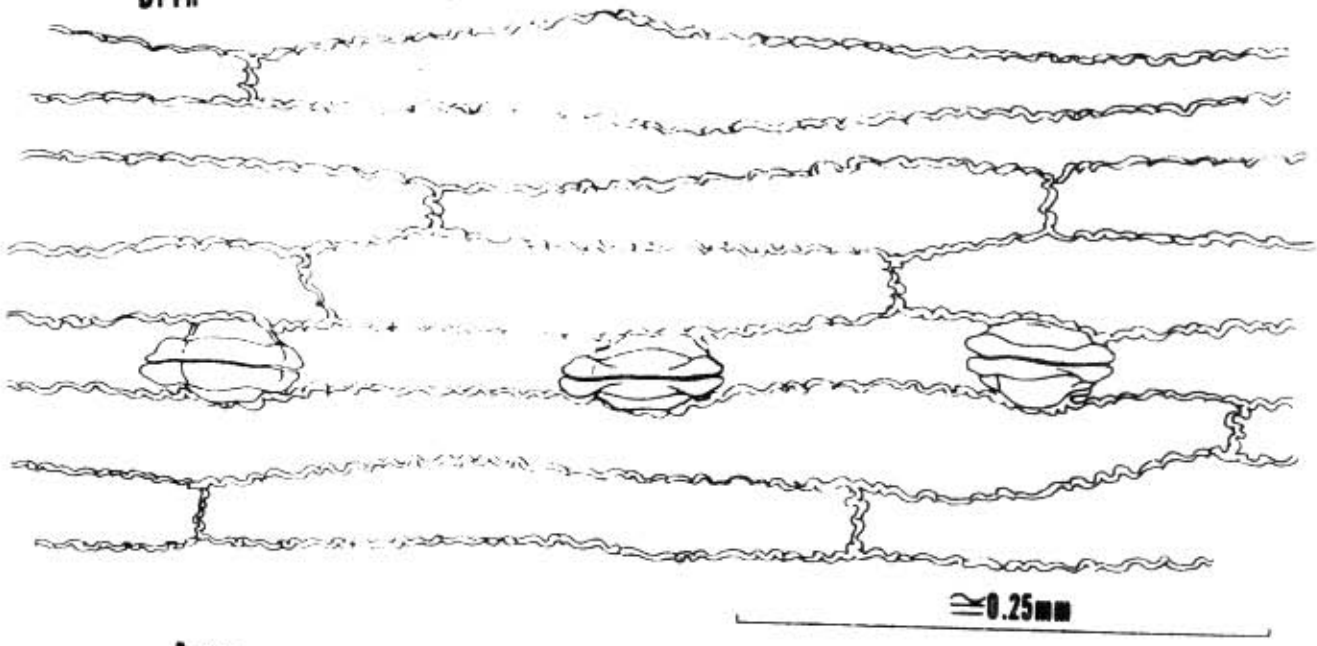


Brin

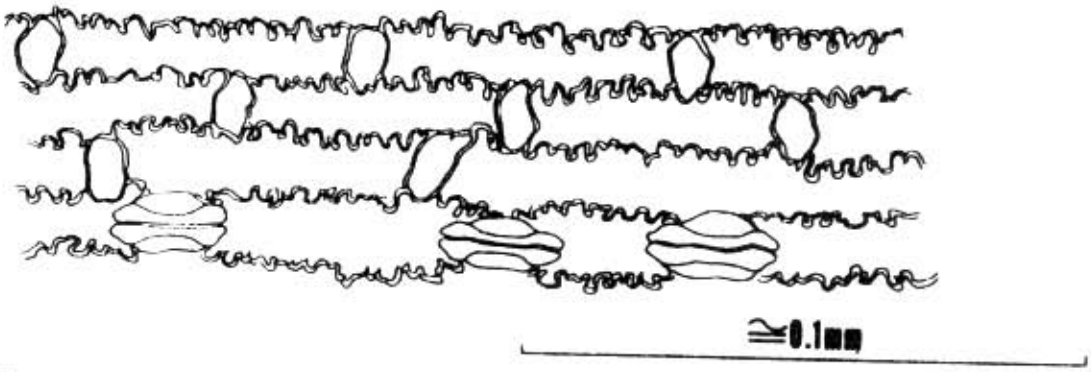


FEOC - Note squared-off stomates, thickened guard cells, loopy cell walls. Could be confused with very young *Agropyron* or BRIN. POPR - stomates rectangular-elongate, silica bodies tall and narrow. Companion cells parallel-sided. BRIN (upper surface) - very sinuous (loopy) thick and dark cell walls. Stomata elongated, with parallel-sided companion cells. Guard cells protrude beyond companion cells. Cork cells conspicuously pitted. Some silica bodies, especially near the veins, tall and narrow. May be confused with *Agropyron*.

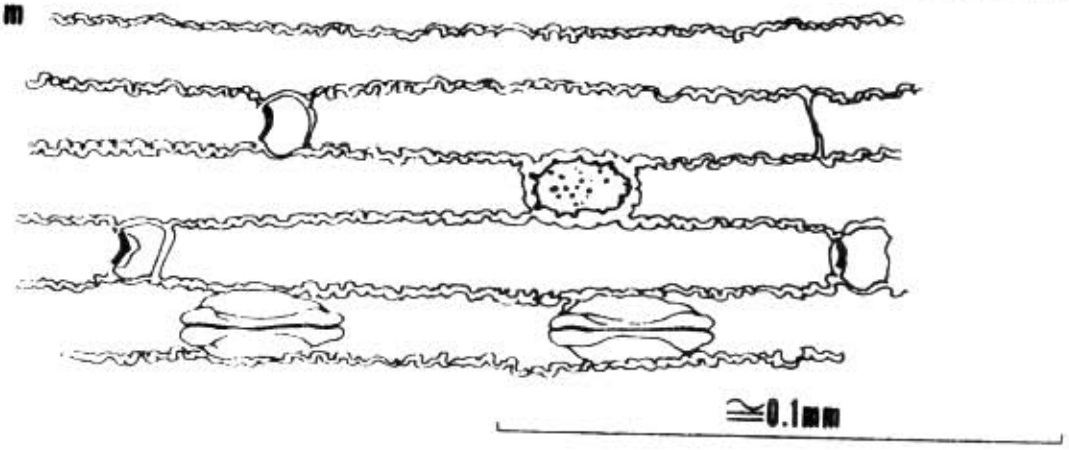
Brin



Agcr

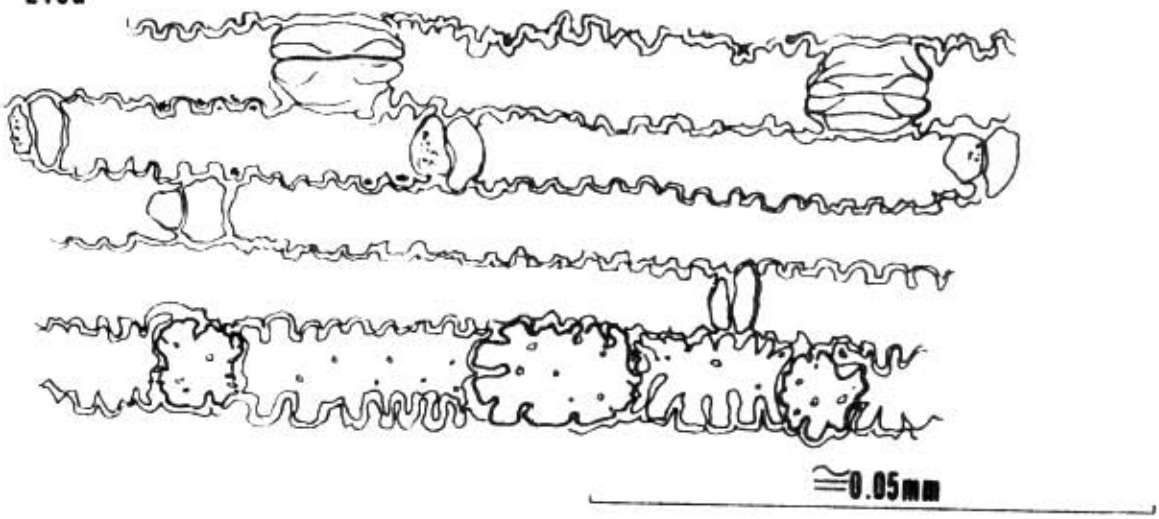


Agsm

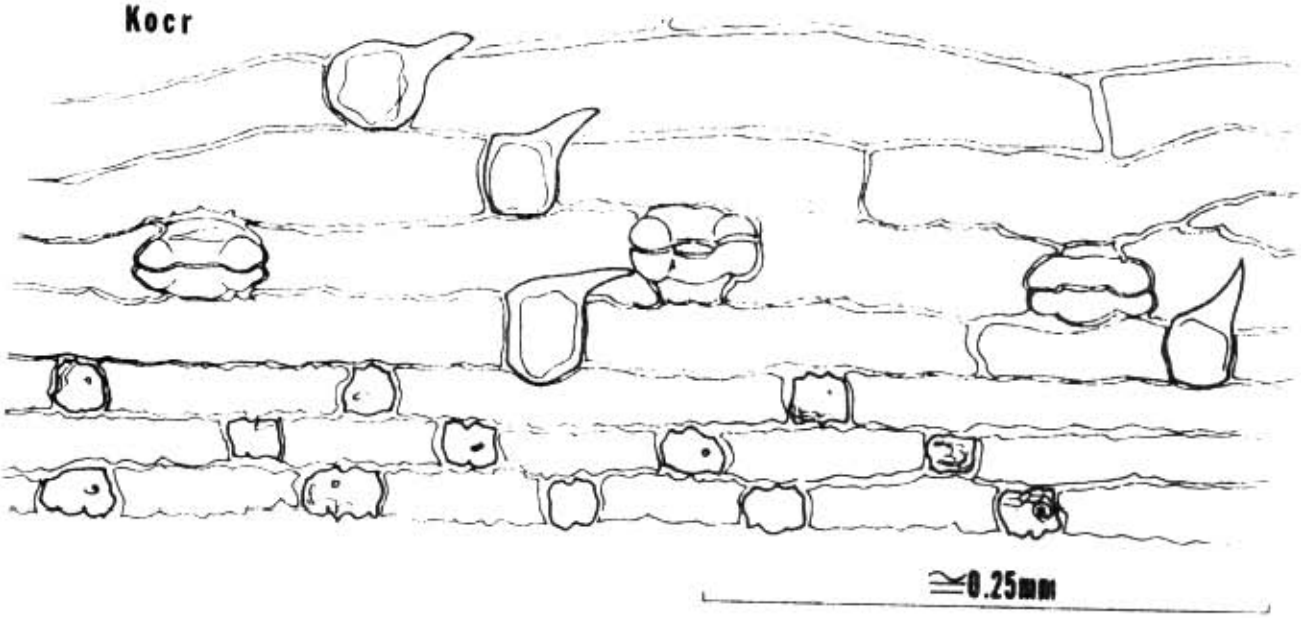


BRIN (underside) - long cells with thin, slightly sinuous cell wall. May be confused with underside to *Triticum*. AGCR - long cells with deeply undulant (sinuous), thick cell walls. Silica-bodies tall and oblong. Prickle hairs long with attenuated points. Stomata narrow and elongated, with low dome-shaped companion cells. AGSM - long cells with less deeply sinuous cell walls than AGCR. Conspicuously pitted cork cells. Silica-suberose bodies diverse in size, but generally constant in shape, with round cork body and sickle-shaped silica body fitting into concavity of cork cell. Stomates vary from round to elongate.

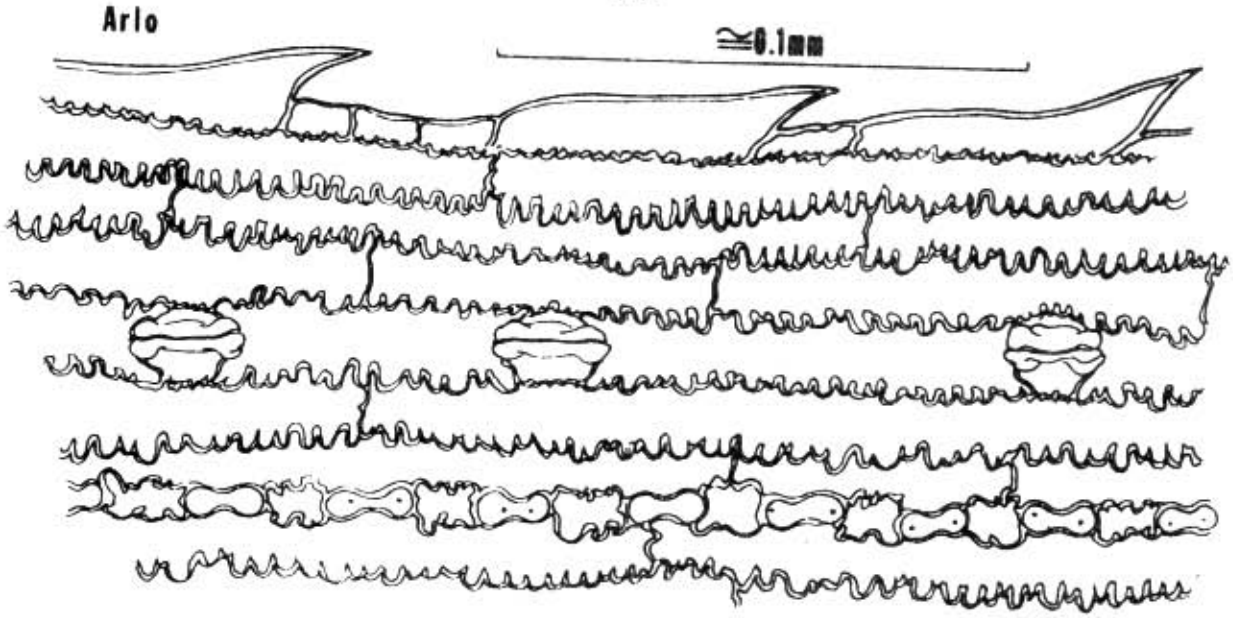
Elca

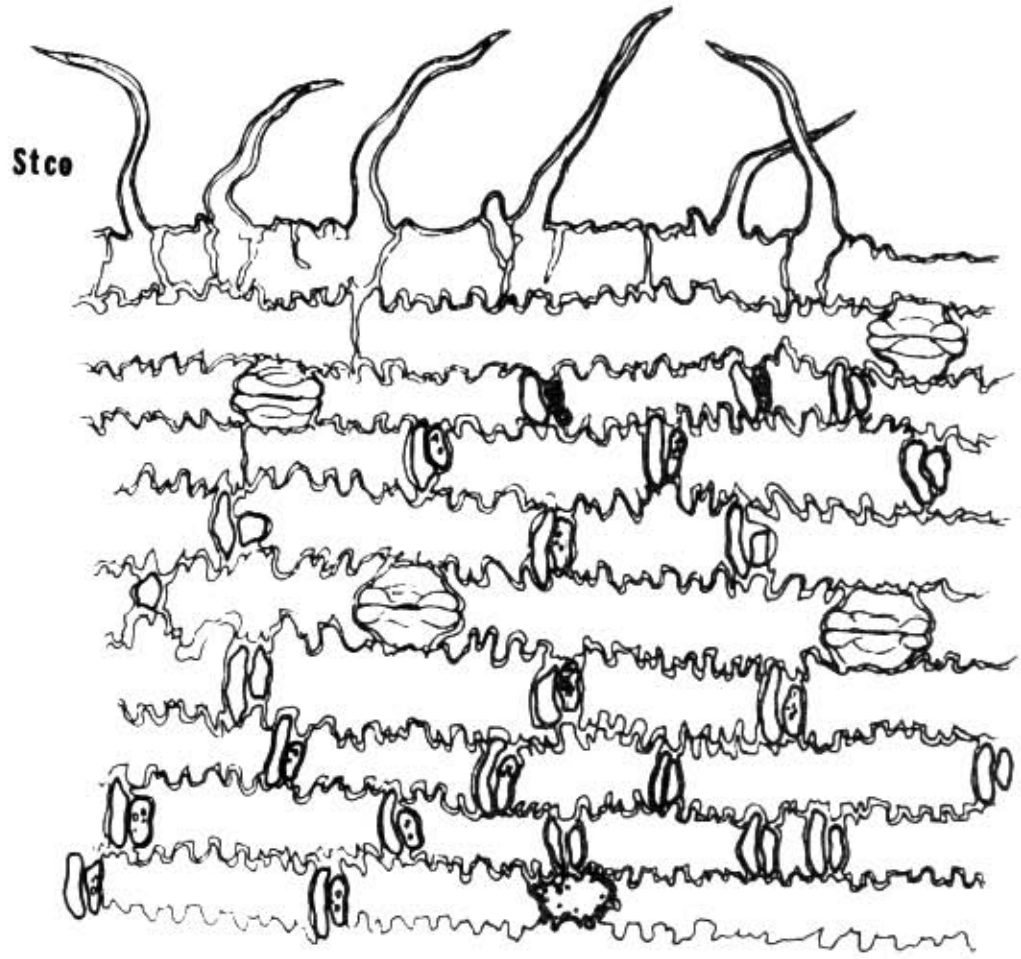


Kocr



ELCA - long cells with thin very sinuous walls, silica bodies each fitting into a concavity in adjacent cork cell, and round, oval, or slightly crescent shaped. Distal cell darker (more silicified) than proximal cell of each pair. (Prickles common over veins.) Stomates with thickened low-domed shaped companion cells.
KOCR - long cells with thin-non-sinuous walls. Stomates with thick, puffy guard cells and thin, parallel-sided companion cells. Prickle hairs shortly pointed, resembling hooks. Silica bodies in rows over veins, generally horizontally elongated, with rounded ends and smooth to sinuous outlines.

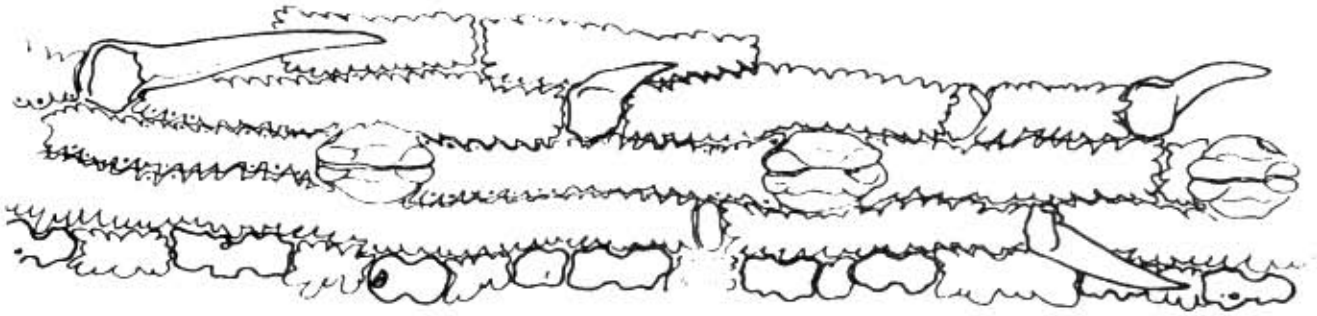




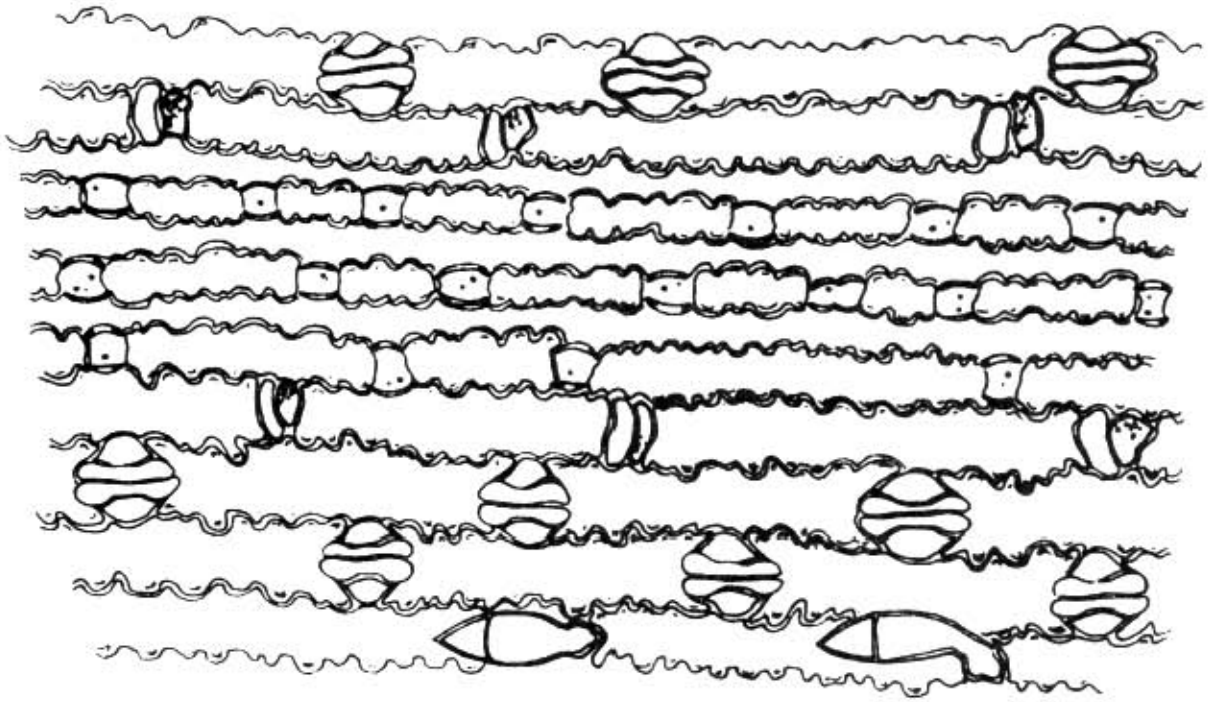
ARLO - long cells with dark, heavy, markedly sinuous walls. Stomata with trapezoidal-shaped companion cells. Short cells absent or uncommon. Silica cells over veins dumbell-shaped, with granules present. STCO - long cells with moderately thick, very sinuous cell wall which is sometimes puckered. Many cork cells with lightened rectangular area on inside. Silica cells almost missing between veins. The silica bodies narrow, fitting into shallow concavities of adjacent cork cells. Cork cells tall and very narrow. Stomata with tall dome-shaped companion cells. Many prickle hairs (trichomes) long and papilae-like; only on one side of leaf blade.

≅0.1mm

Orhy

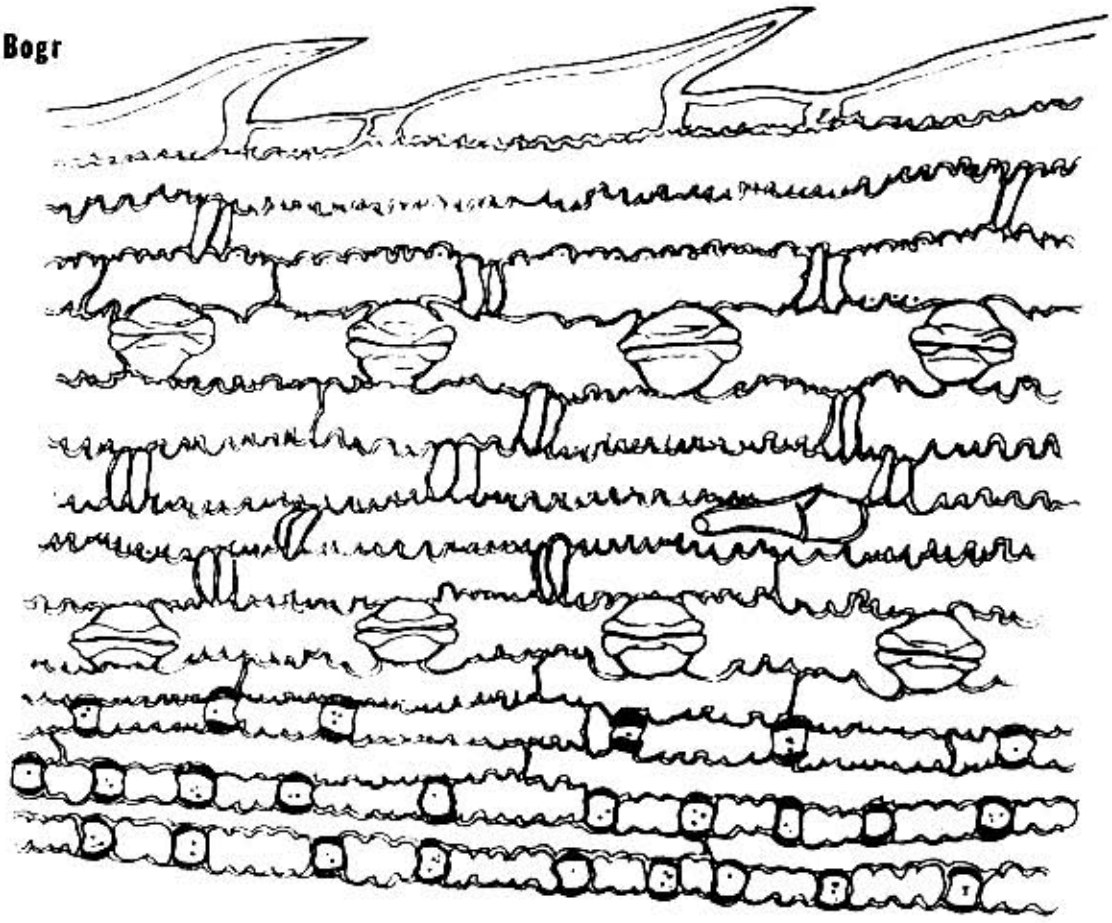


Spcr

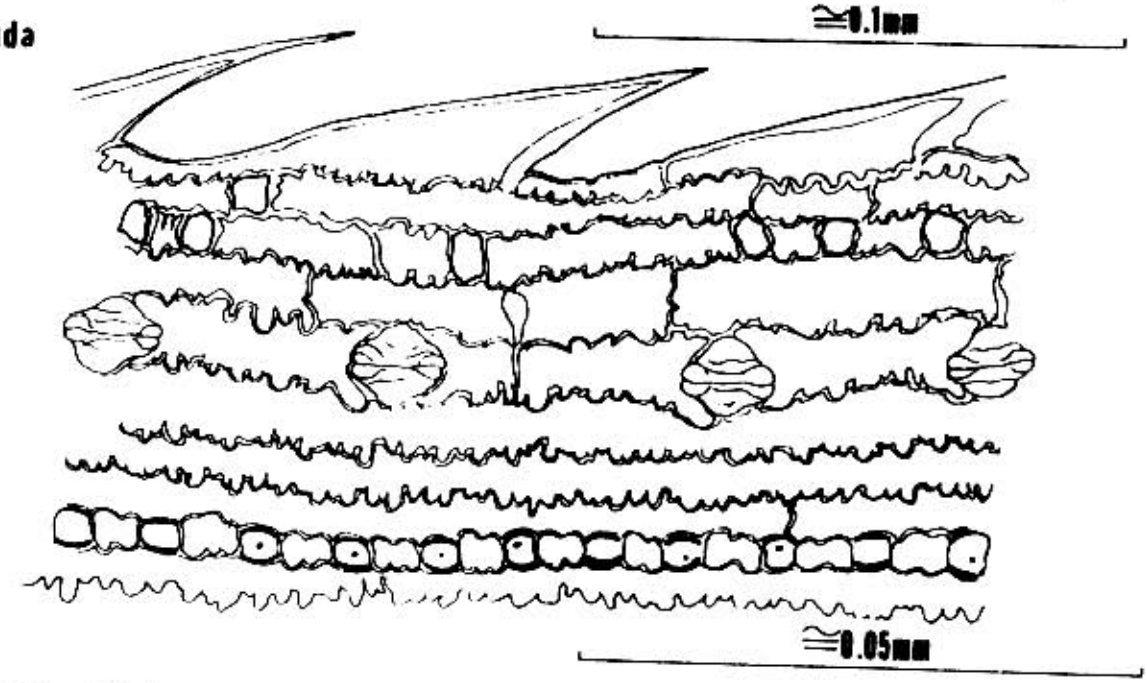


ORHY - long cells with thin, slightly sinuous walls. Short cells over veins, paired or in rows. Silica cells rounded. Silica bodies in rows are elongate, dumbell shaped (X-shaped) occasionally with granules. Stomates with rounded companion cells. SPCR - long cells with medium-thick, sinuous, puckered cell wall, interstomatal cells with concave ends. Many 2-celled asperites. Silica cells round to eliptical, fitting into concavity in adjacent tall, narrow cork cell. Stomata with triangular (high peaked) companion cells. Short cell over veins or rows, parenthesis-shaped with granules (darkest at corners).

Bogr

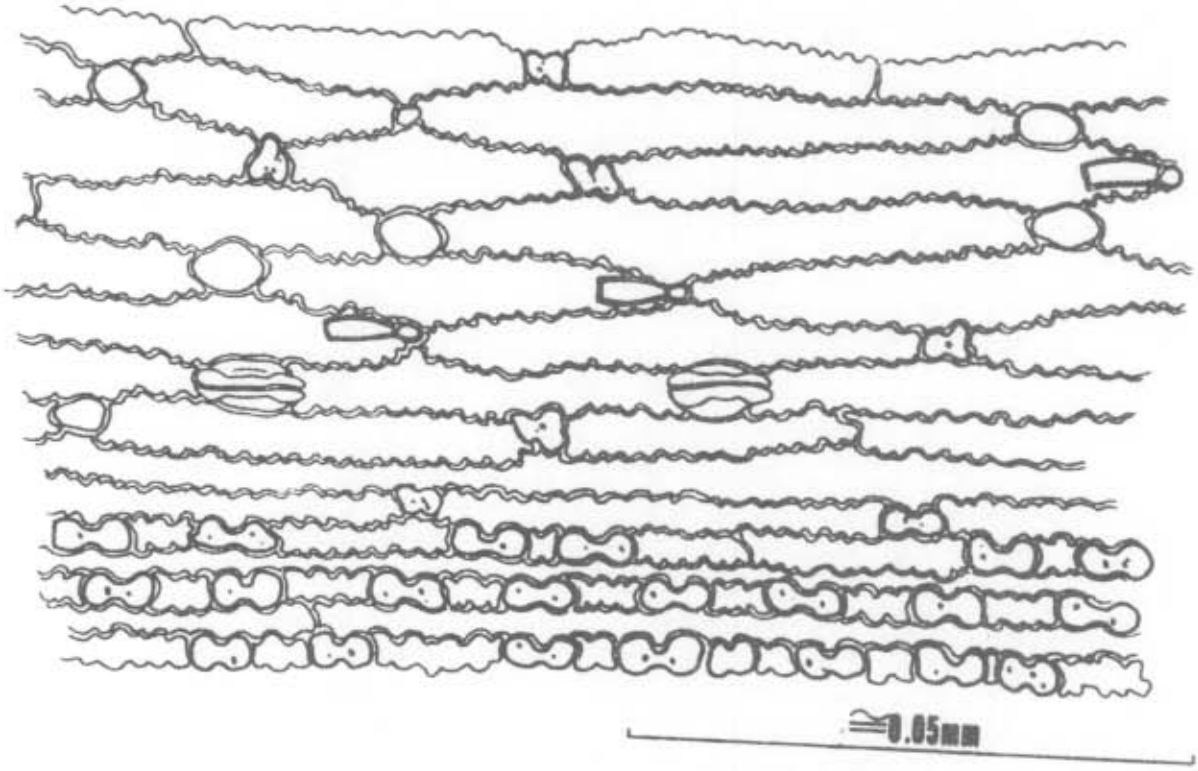


Buda

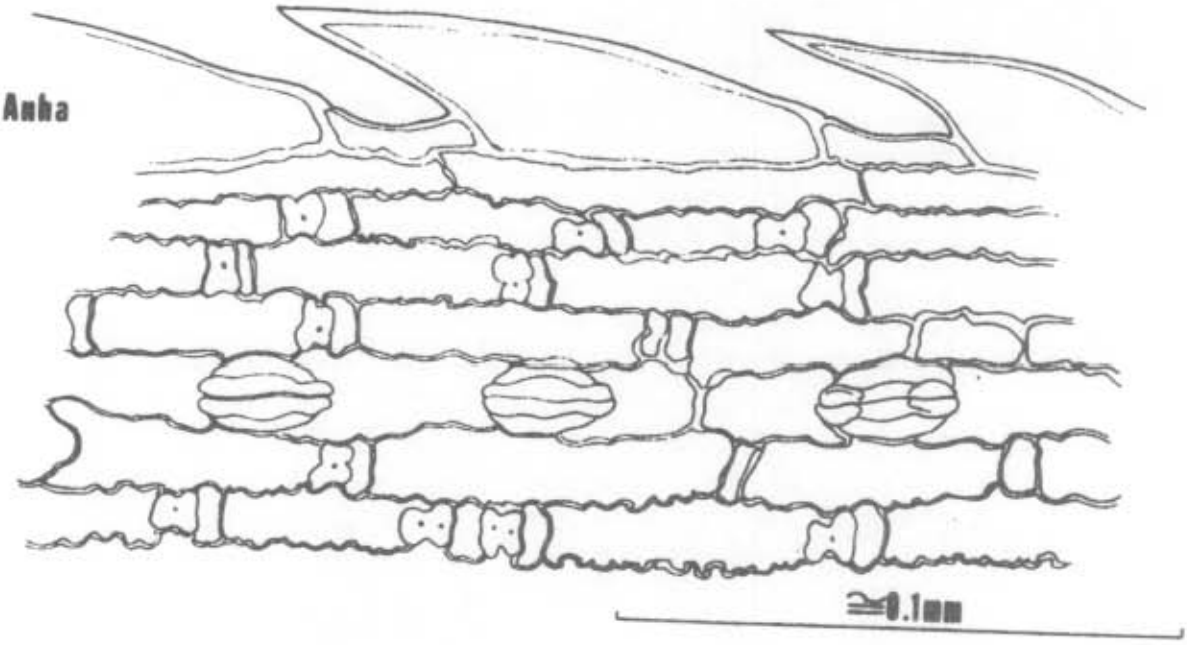


BOGR - long cells with distinctly seen, tightly undulating walls. Rounded stomates with elongated (protruding) guard cells and high-domed companion cells. Two-celled asperites are common, these being foreshortened, with a rounded tip. Silica-suberose bodies distinctly separated, tall and narrow, and clear. Silica bodies in numerous rows over veins, having a heavy, angular parenthesis shape. BUDA - long cells with thick, shallowly undulant walls. Short cells parenthesis-shaped in rows over veins; very narrow silica bodies scattered throughout, not in pairs (silica-suberose). Thick cuticle often obscures stomates. Stomates diamond-shaped with triangular companion cells. Asperites (2-celled) rare.

Seit

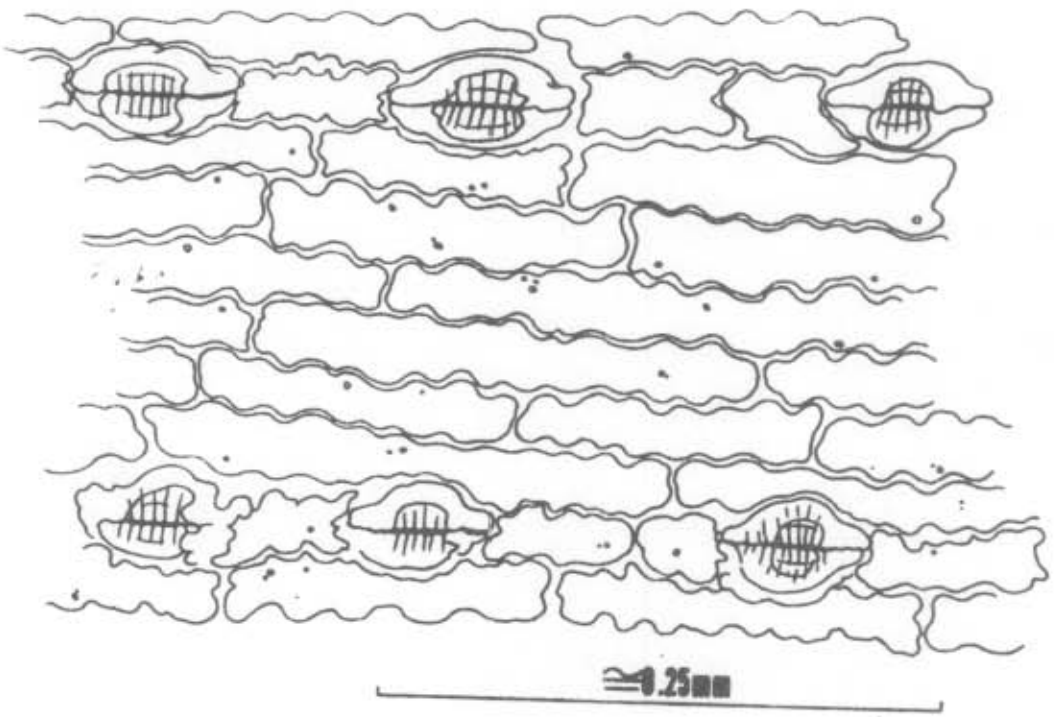


Anha

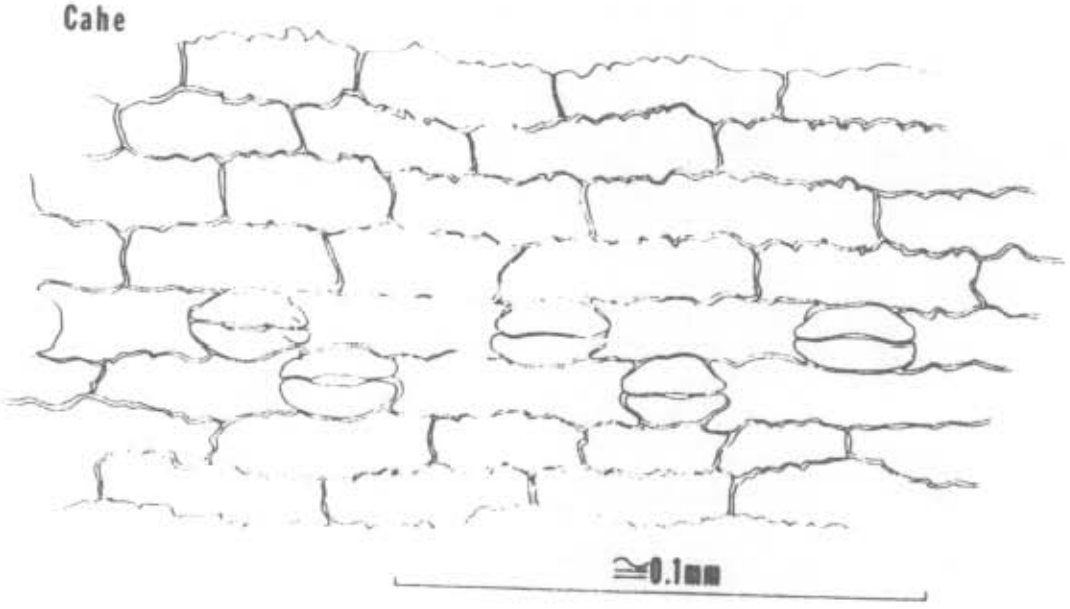


SEIT - long cells long and diamond shaped, with shallowly undulant walls. Asperites common (2-celled with pointed tip). Stomates oval and narrow. X/or butterfly-shaped silica bodies. Rows of X- or dumbell-shaped short cells over veins (shorter than in ARLO, heavier than in ORHY). ANHA - very large prickles on margin of blade; long cells with thin, smooth to faintly undulating walls. Stomates oval, with thick guard cells and thick companion cells. Distinct, X- or butterfly-shaped silica-suberose bodies.

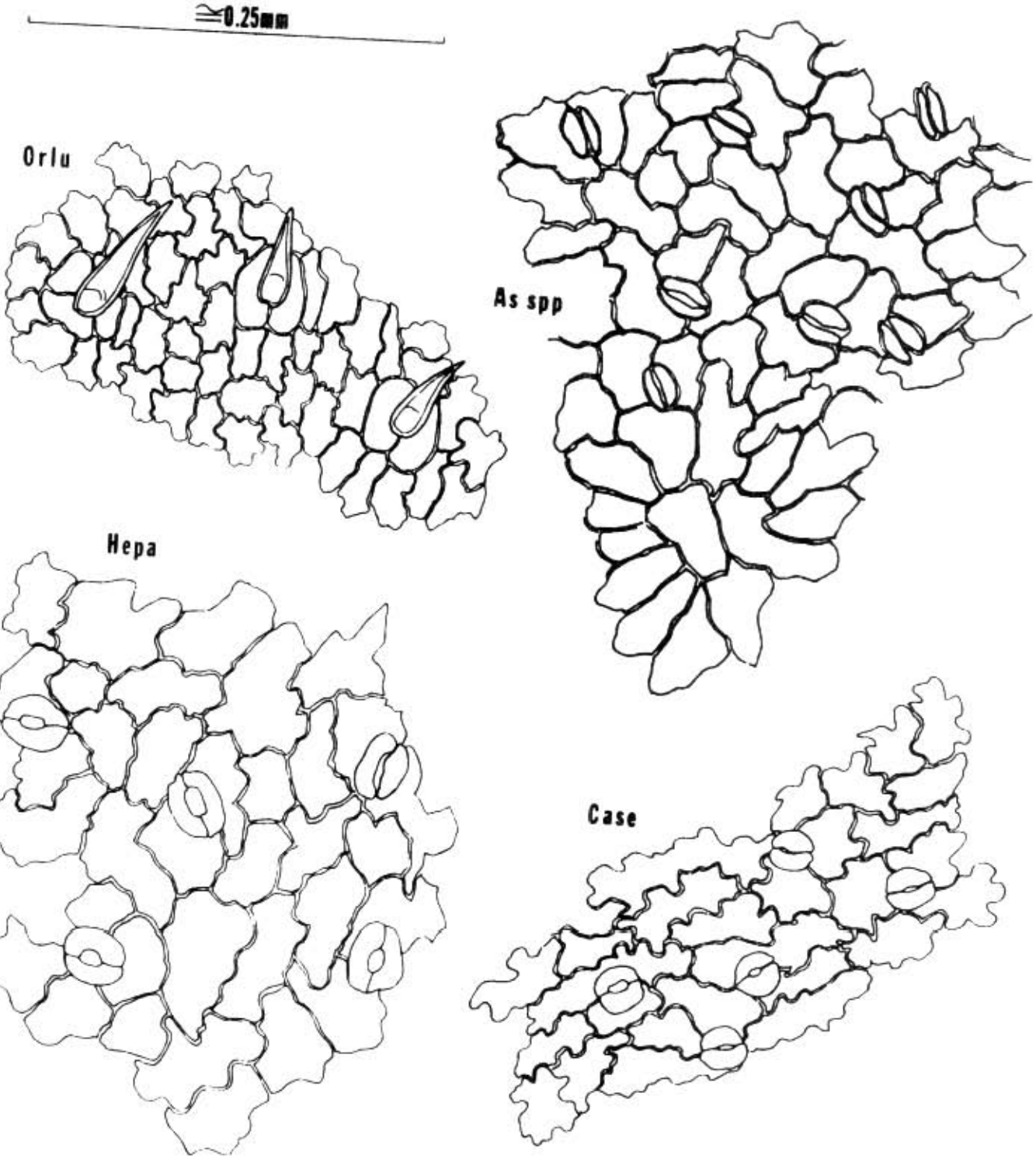
Eqka



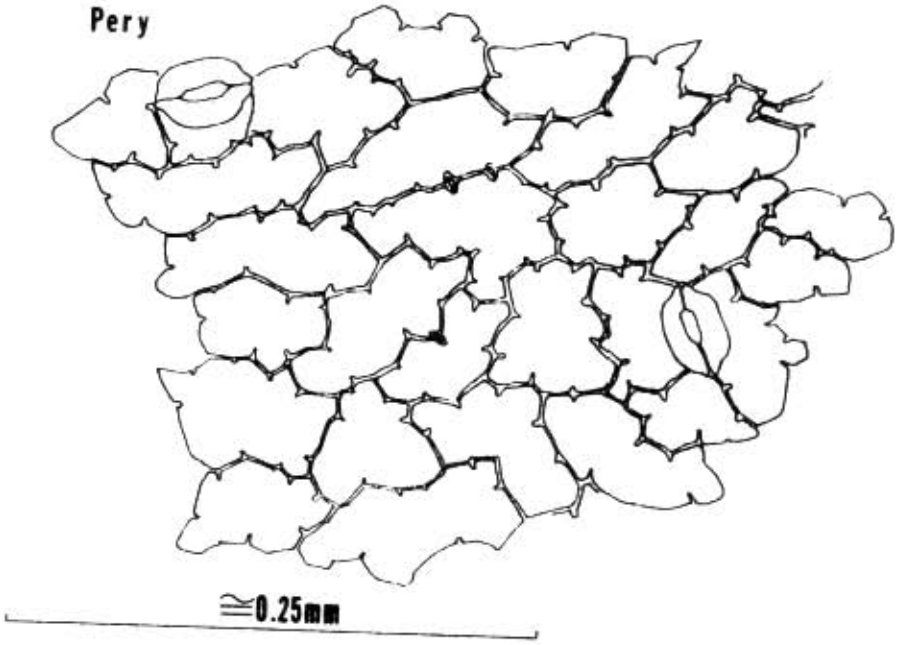
Cahe

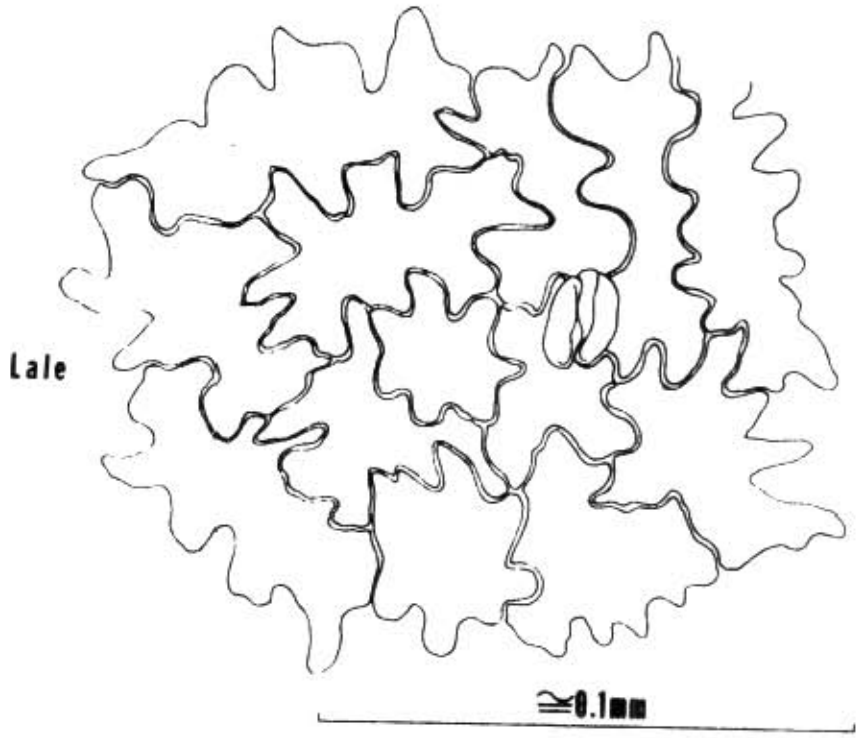


EQKA - thick obscuring cuticle. Llongated cells with heavy undulating walls. Granules present in cells. Can be easily recognized by very unusual stomates. CAHE - blocky, rectangular cells, with dentate walls. Stomates with thick companion cells.

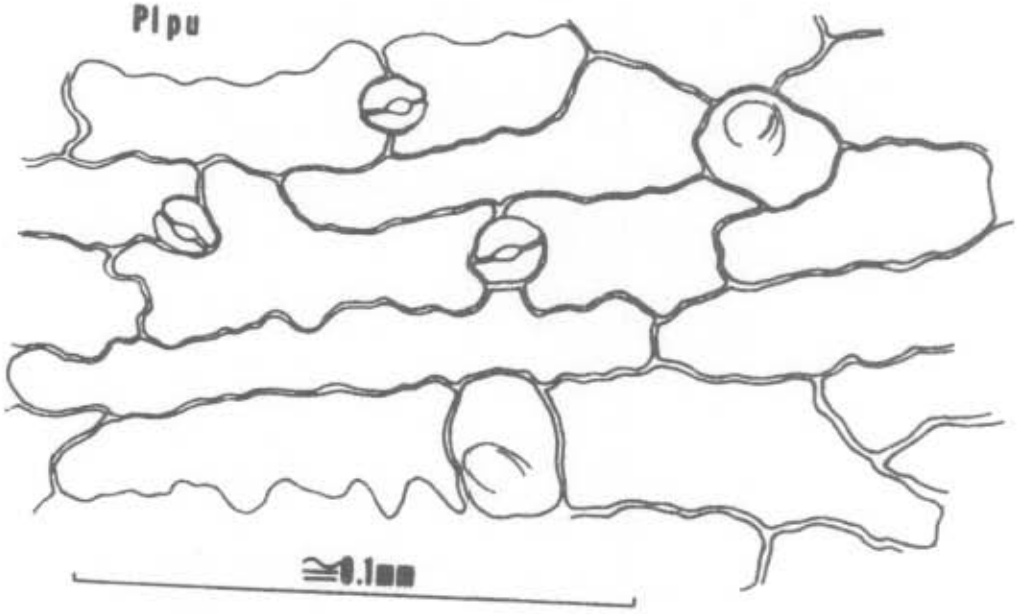


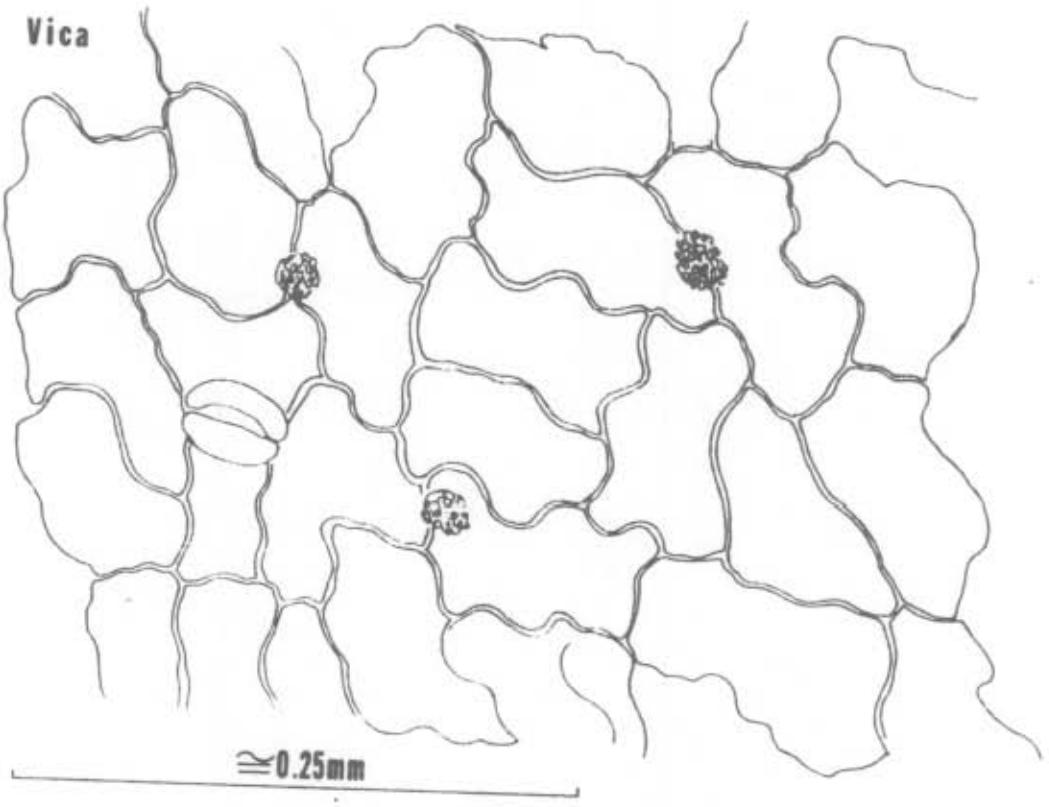
Epidermal cells of irregular shape. Note small size of cells and stomates in AS SPP, CASE, and ORLU, and radial arrangement of cells around trichome attachment of AS SPP. AS SPP sometimes has a double-wall appearance. SARE looks like ORLU; SINE resembles CASE. Species which resemble AS SPP are MESA, EVNU, GIAG, WYAR, and LARE. Those which resemble HEPA are: THME, *Melilotus alba*, *Taraxicum officinale*, *Lupinus argenteus*, *Oenothera atrigosa*, *Vaccinium scoparium*, and LASC.



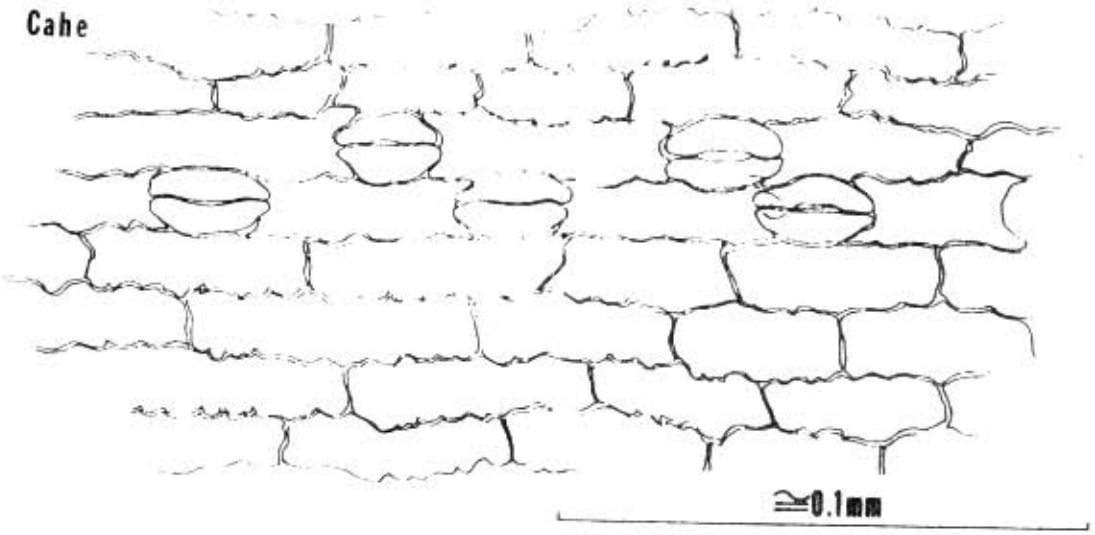


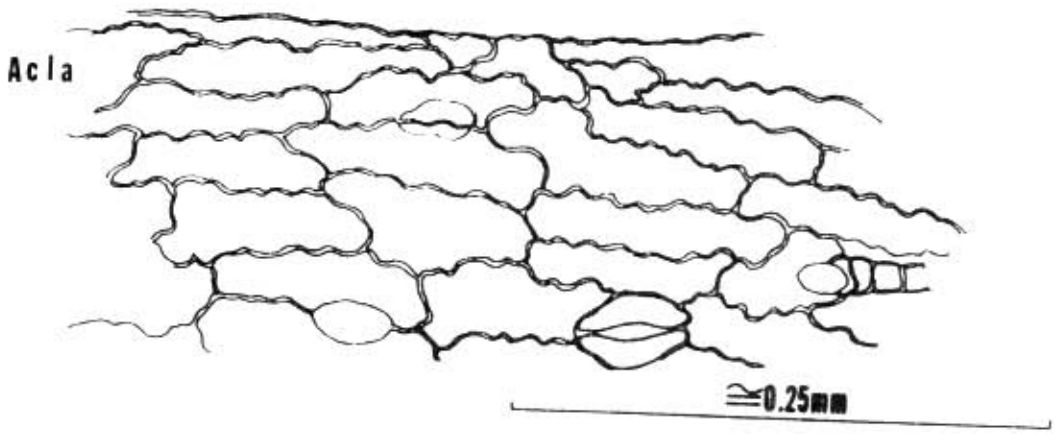
Epidermal cells of irregular to "jigsaw" shape. Note "dotty" or "notched" appearance of PERY cell walls. Species which resemble PERY are: SCBR, MESA (not dotty), ANSE and PEALP. Other species with the extreme "jigsaw" appearance of LALE are *Vicia* sp., *Veronica peregrina*, PLPU, BAOP, GABO, ARFE, and LEDE.

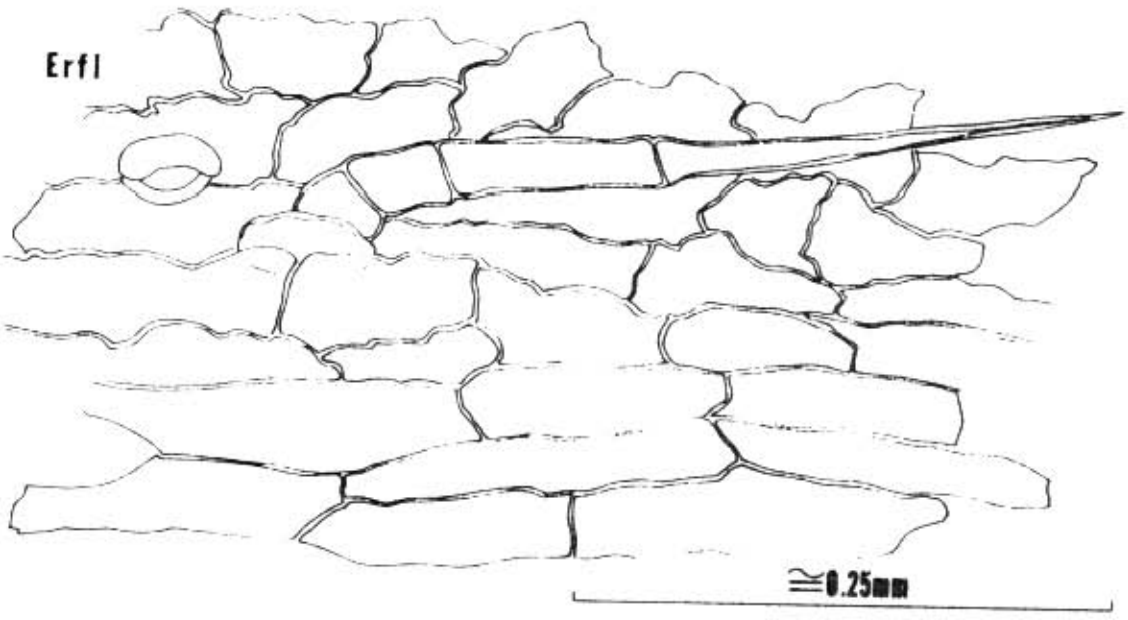




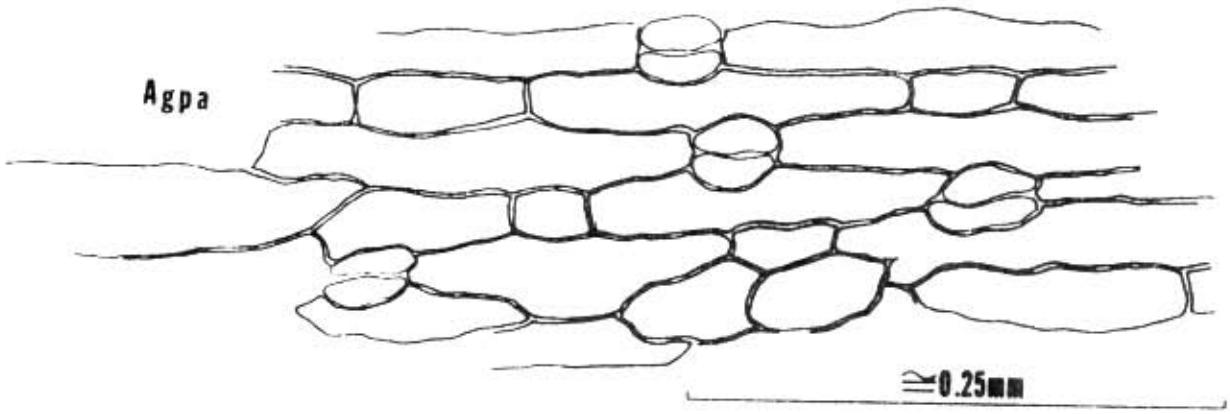
Elongated epidermal cells with irregular cell walls. Note large round cells where trichomes attache on PLPU. PLPU sometimes tends towards a jigsaw appearance as in LALE. Species which resemble VICA are: *Sibbaldia procumbens*, GABO, POFR, SINE, THTR, ASTA, and *Thlaspi arvense*. Those which resemble PLPU are *Gilia laxiflora*, *Hymenopappus filafolius*, and TRPR.

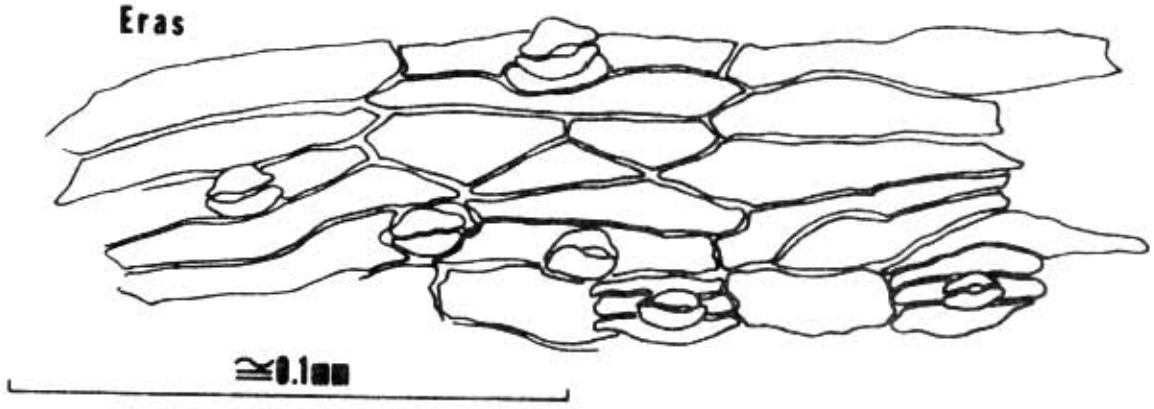


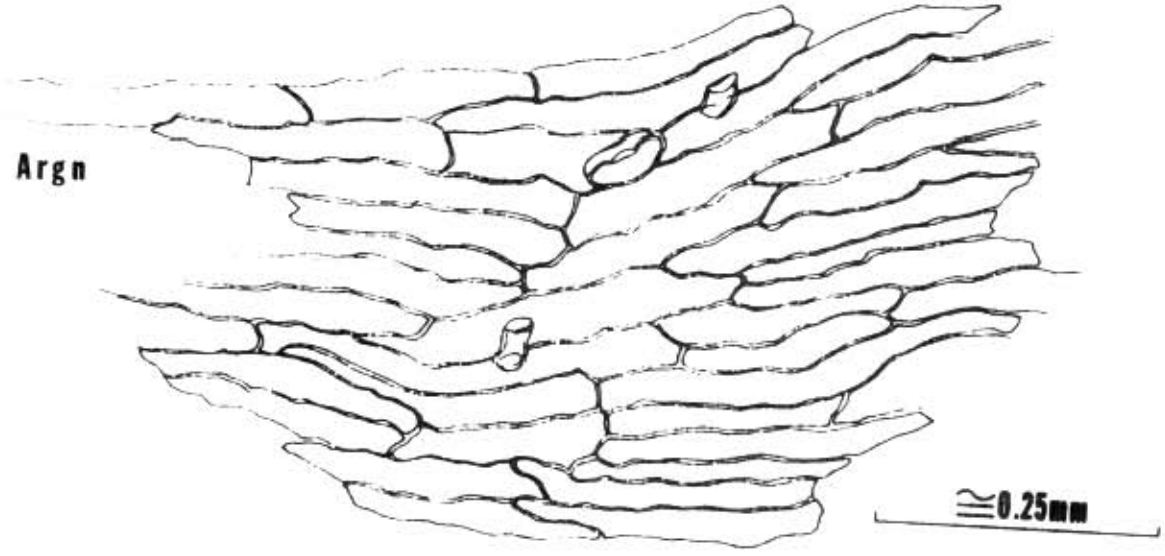




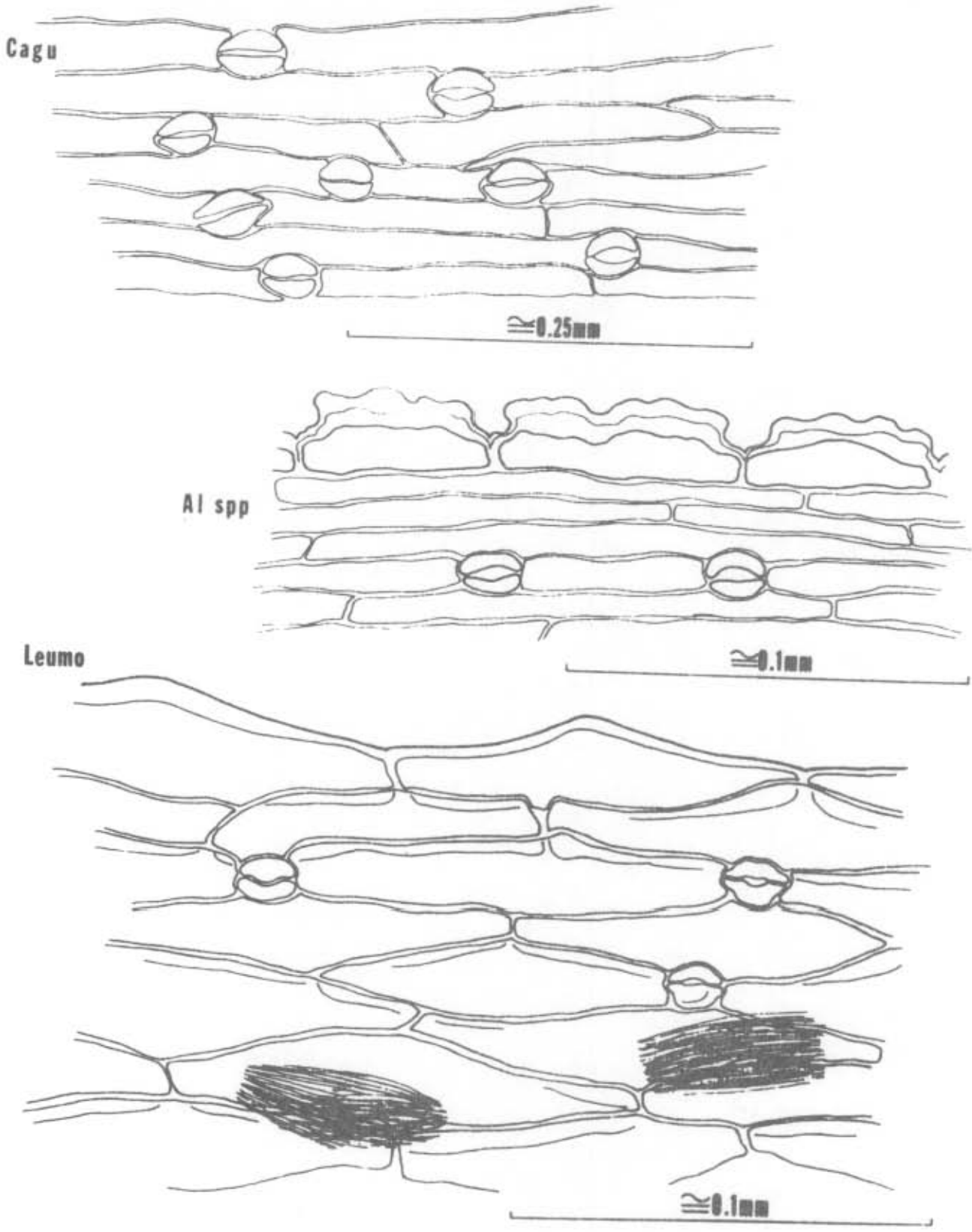
Elongated epidermal cells with irregular to smooth cell walls. JU SPP is very similar to CAHE. Species similar to ACLA are *Phlox caespitosa*, LEPU, HEPE, and OECO. *Eriogonum bellidinatum* and ERCA resemble ERFL.



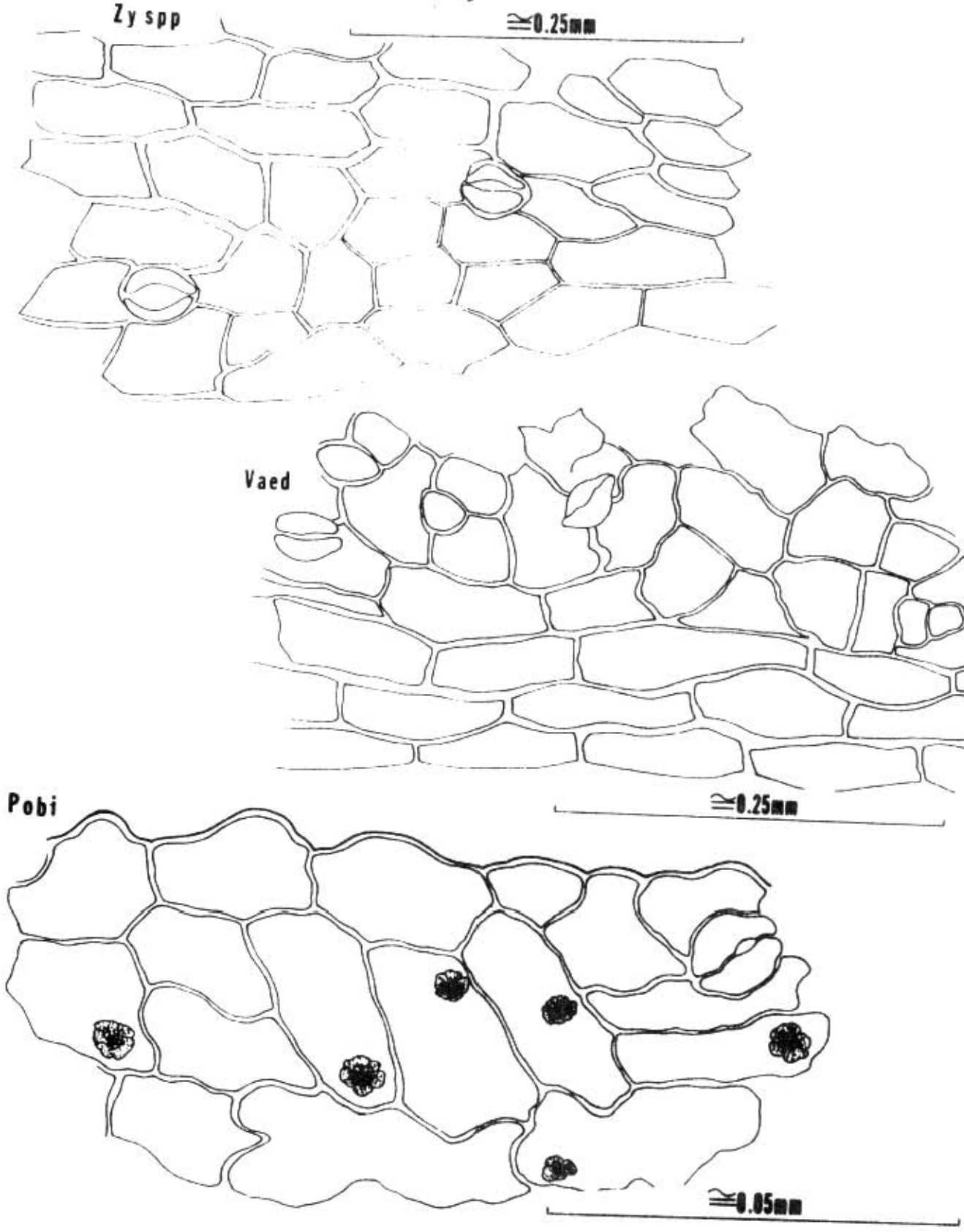




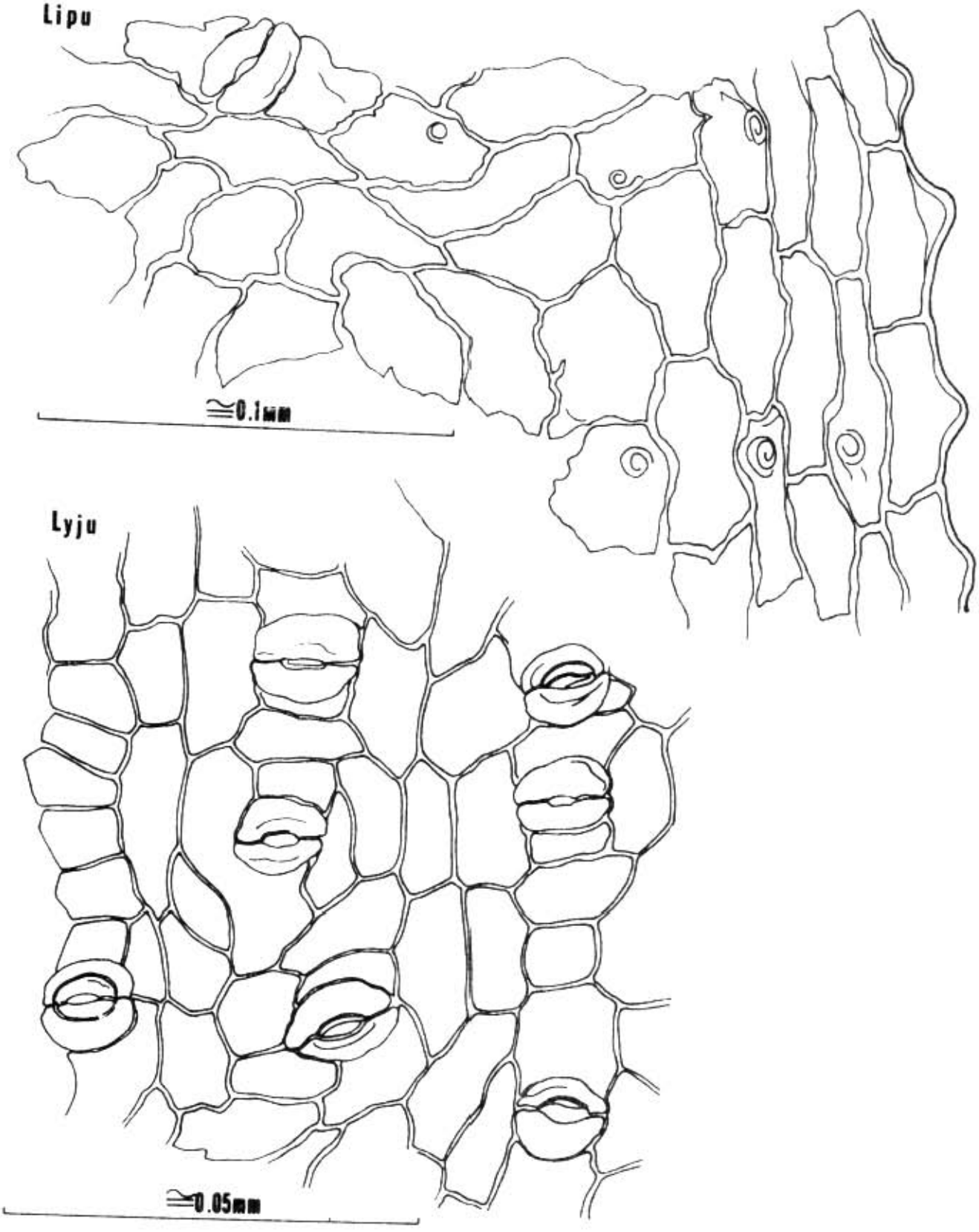
Elongated epidermal cells with smooth cell walls. Note polygonal shape of cells and unusual companion cells of ERAS. CRFE is similar to ERAS.



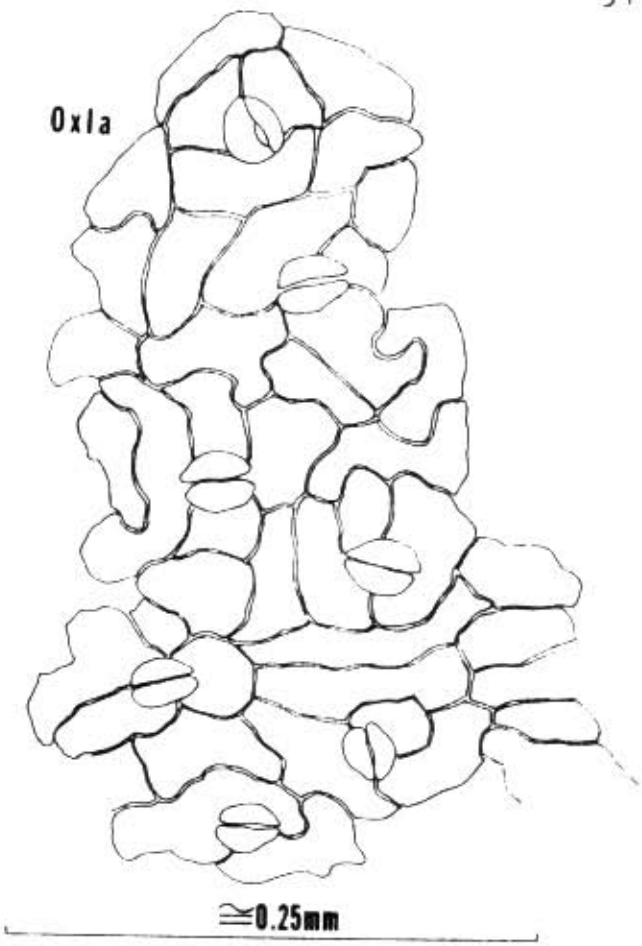
Elongated linear epidermal cells with smooth cell walls. Note bristle bundles on LEUMO.

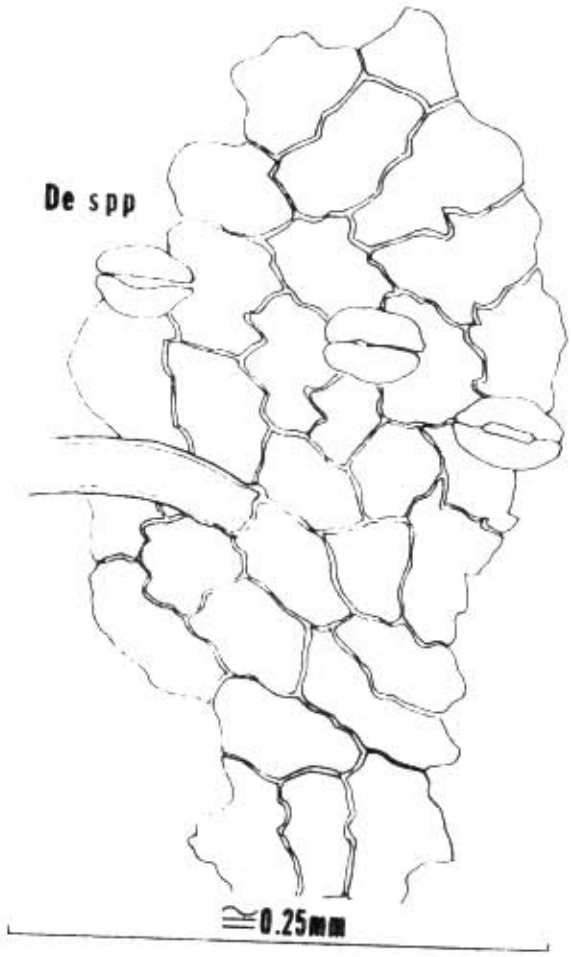


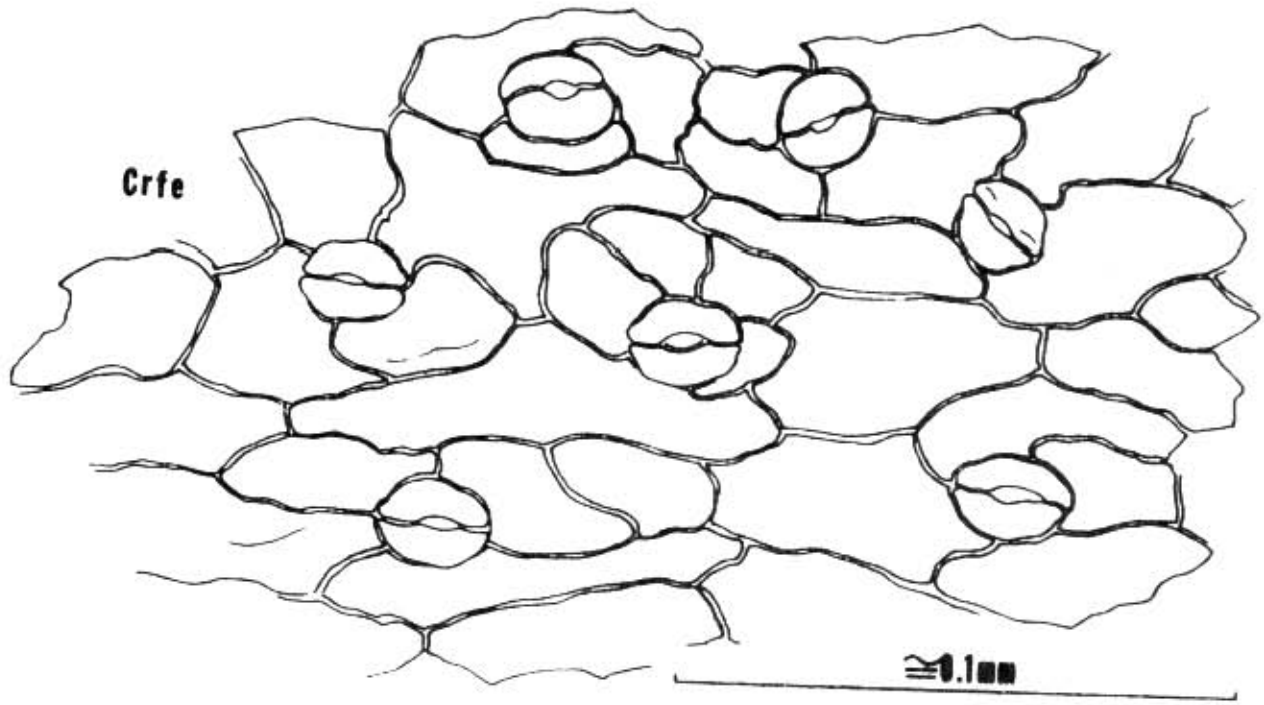
Elongated to polygonal epidermal cells. Note druces in POBI, sharp corners of ZYEL. Species very similar to ZYEL are YUGL, STPA, and TROC. YUGL and TROC have bristle bundles. YUGL is distinguished by very unusual stomates. SOSE is similar to POBI.



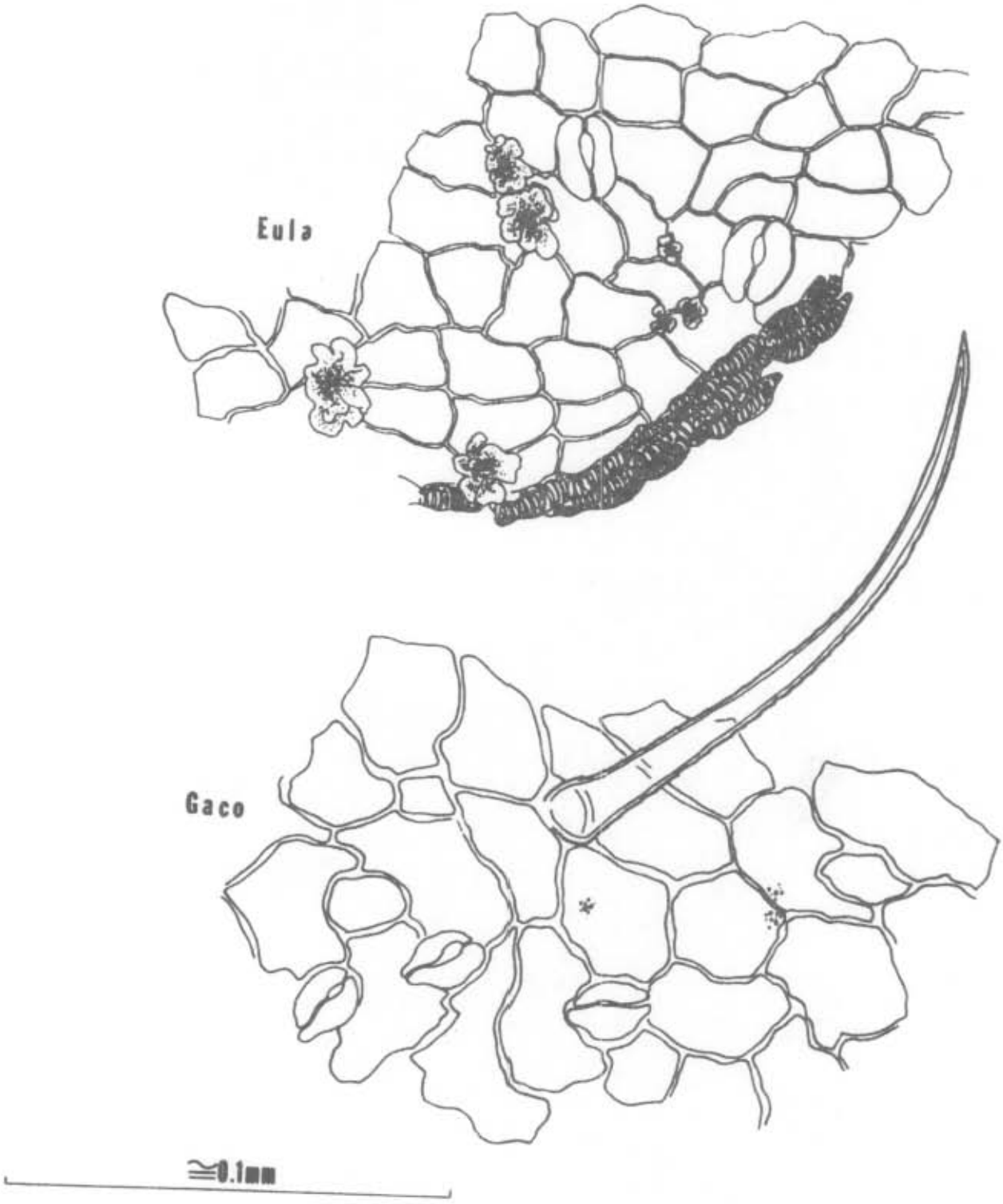
Elongated to polygonal epidermal cells. Note large stomates in both species, and heavy companion cells in LUJU.



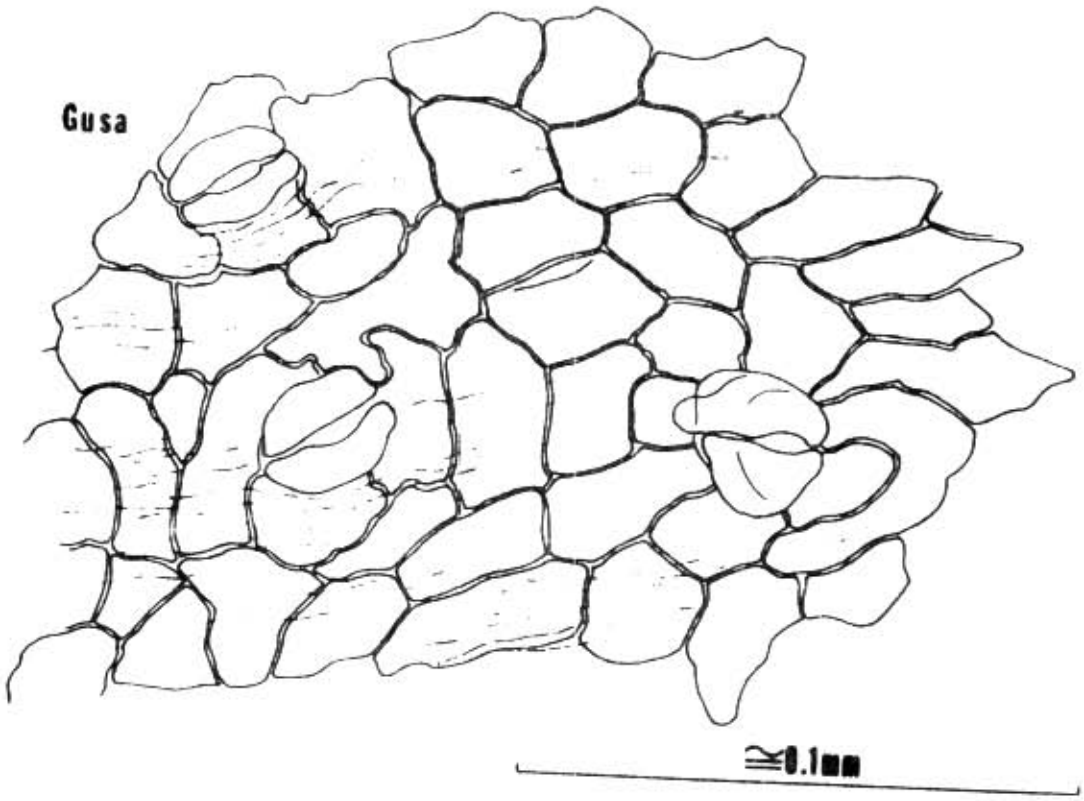


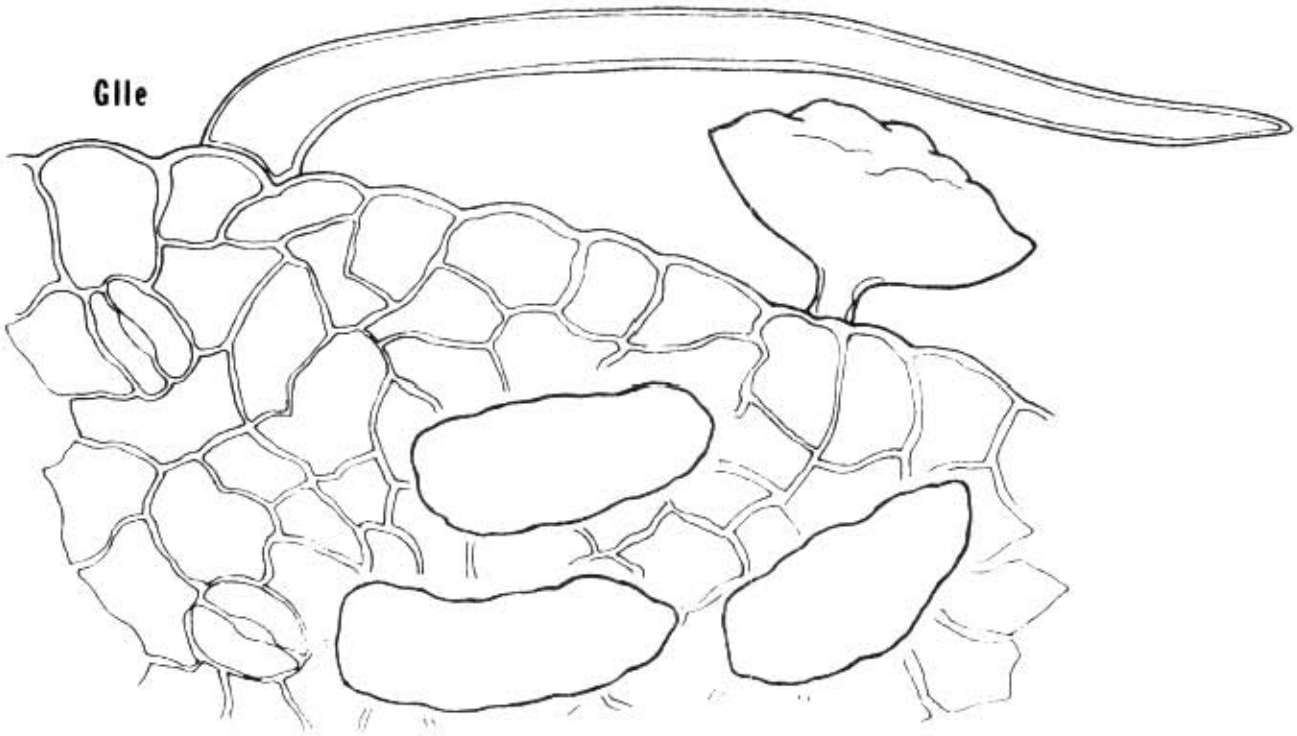


Polygonal epidermal cells. Species similar to DE SPP are *Leaquevilla linloviriana*, *Wilhaldia procumbens*, GEFR, and GACO. Species resembling CRFE and OXLA are ERED, CHNA, *Trifoliumnanum*, ASTA, and HASP. The epidermal cells of DE SPP vary in shape from polygonal-smooth to irregular.



Polygonal epidermal cells. In EULA, the epidermal cells are usually obscured by the numerous druces and trichomes. PECA resembles GACO.

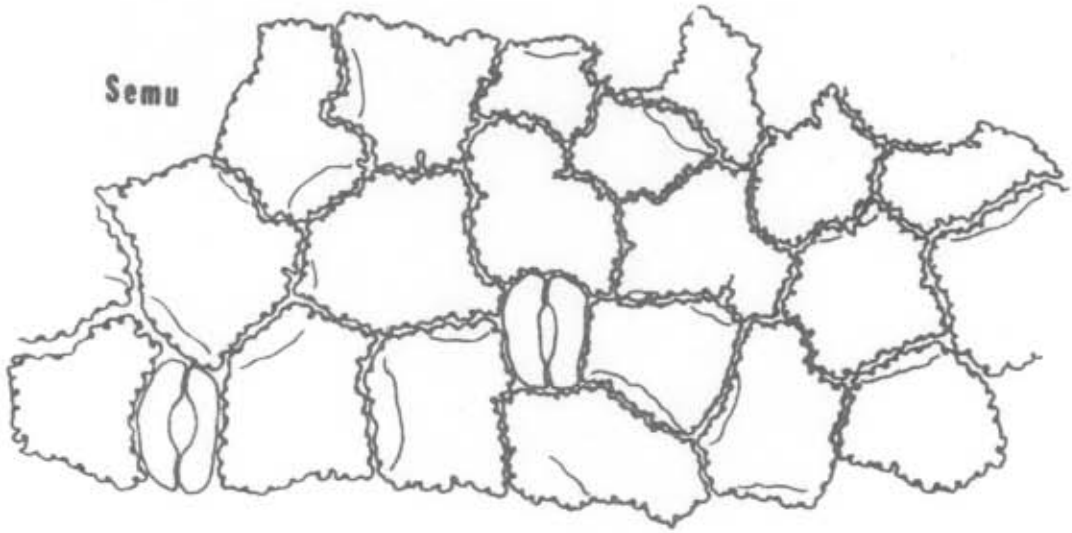




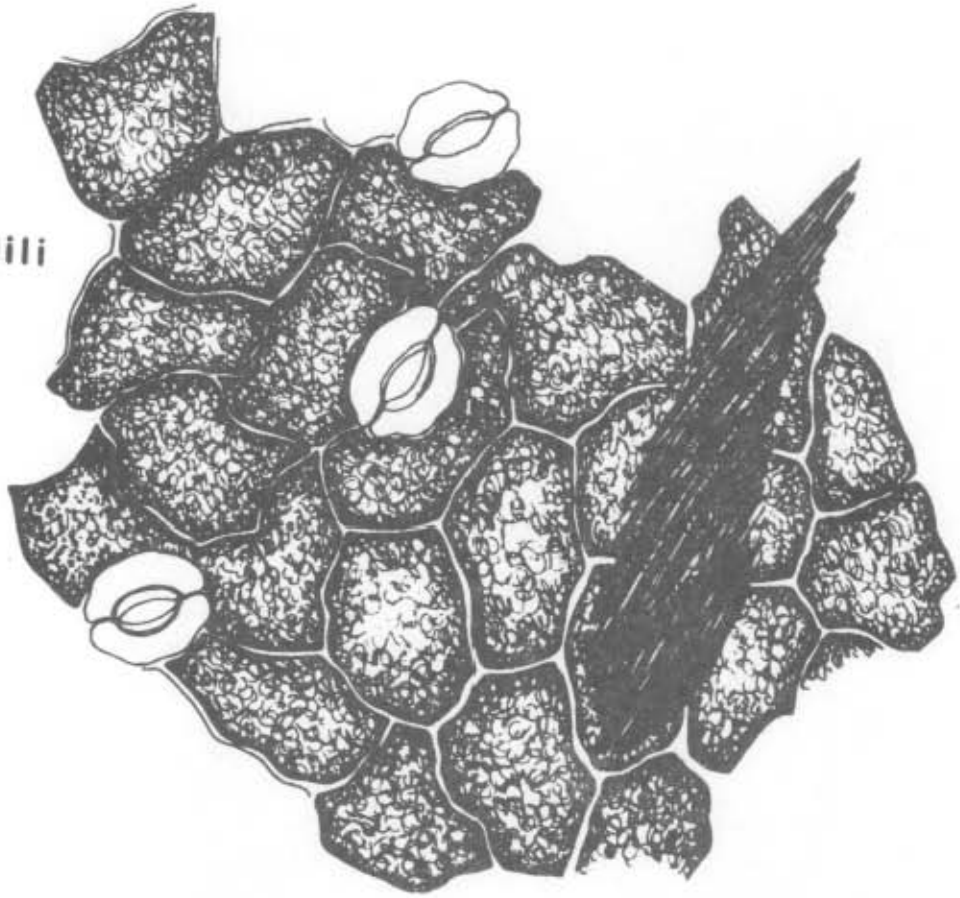
Polygonal epidermal cells. Note wrinkled appearance of GUSA. SPCO resembles GUSA, but lacks these fine striations. GLLE is readily identified by the numerous luminescent glandular trichomes covering its surface.

≅0.1mm

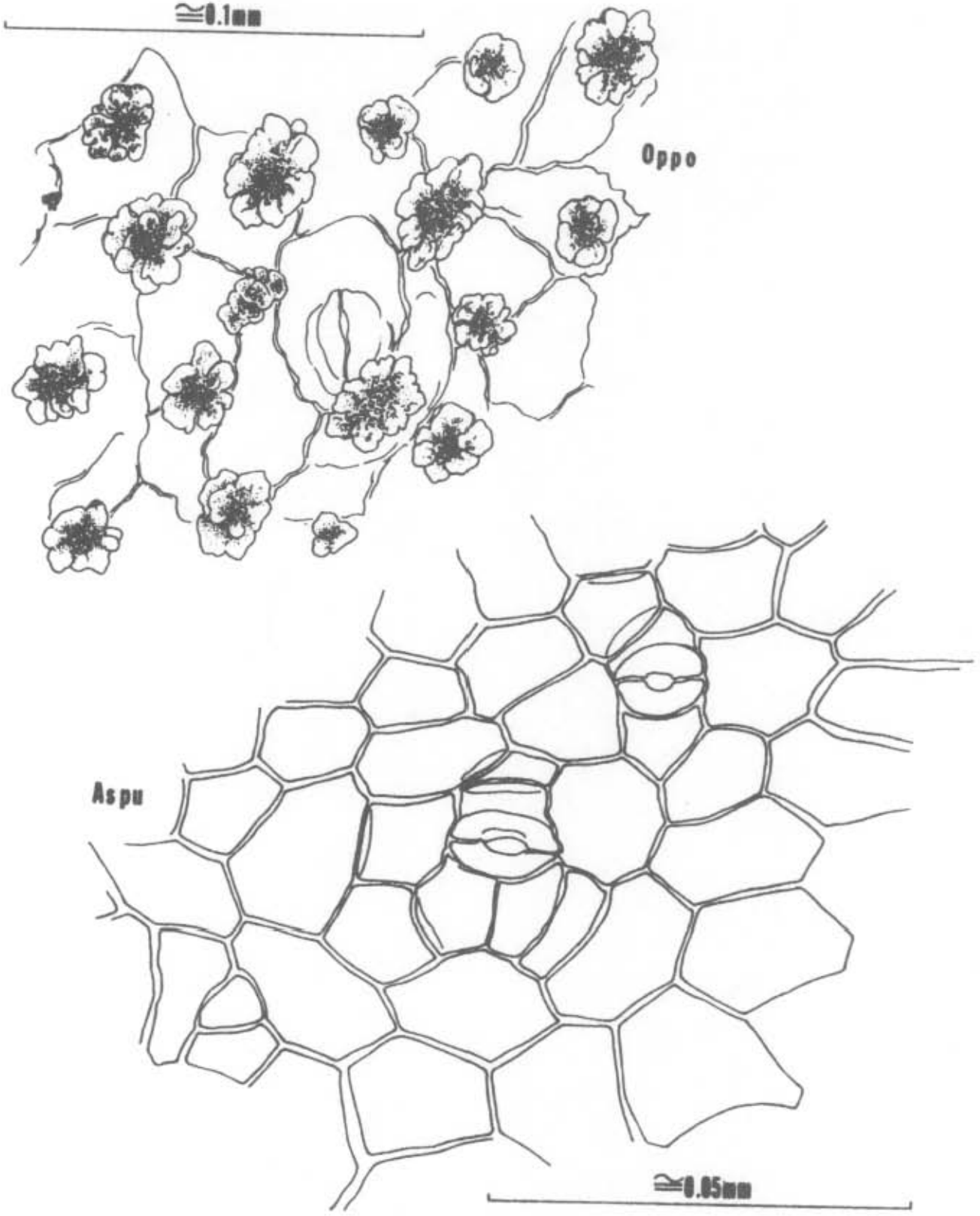
Semu



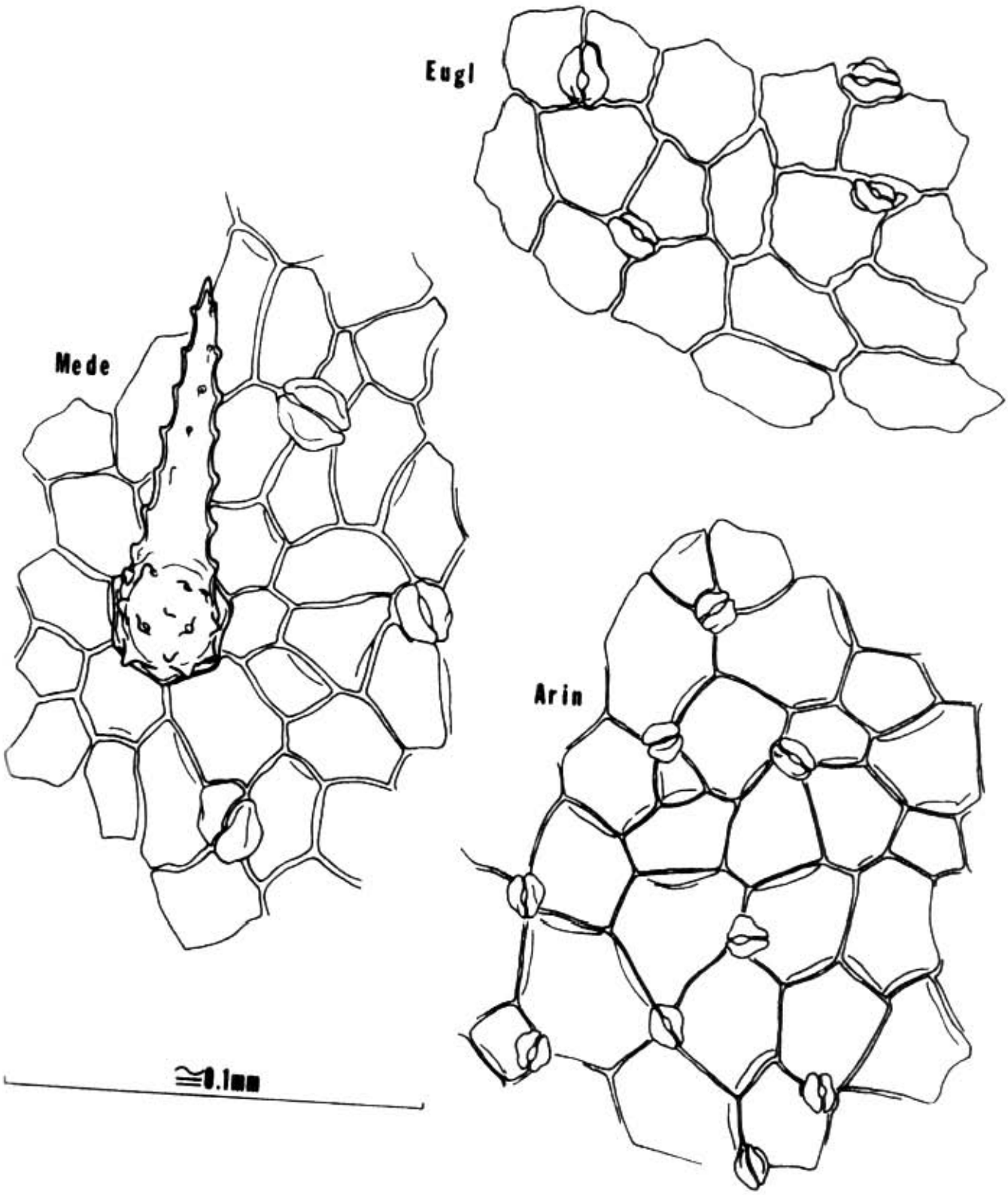
Mili



Polygonal epidermal cells. Note extremely dotty cell walls of SEMU. ABFR is very similar to MILI, even to the mottled texture of the cells, and the bristle bundles.



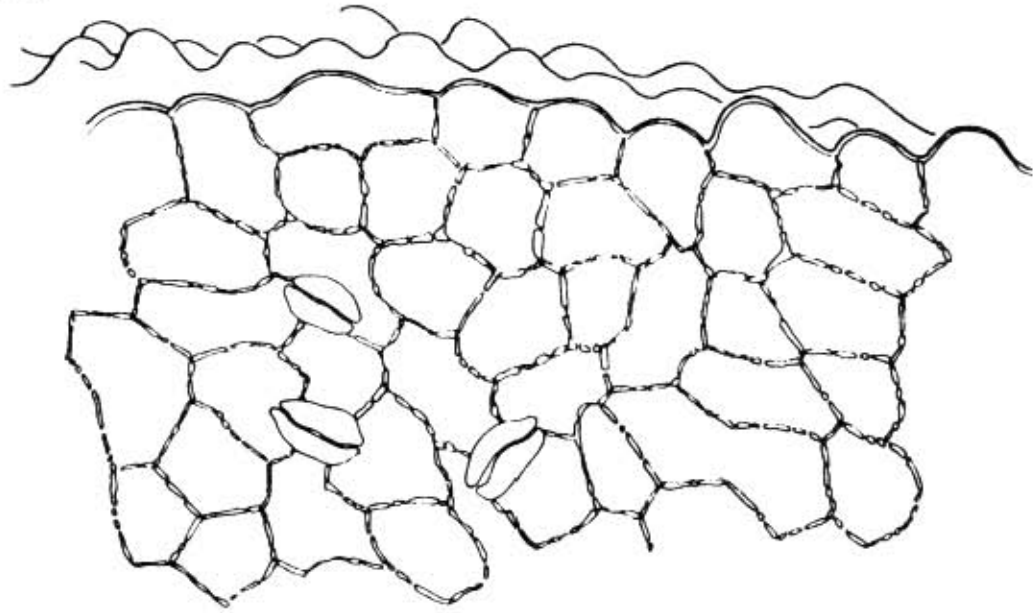
Polygonal epidermal cells. In OPPO the epidermal cells are obscured by numerous large druces. Species which are similar to ASPU are *Rosa* sp. and NOCU. Note unusual companion cells of ASPU.



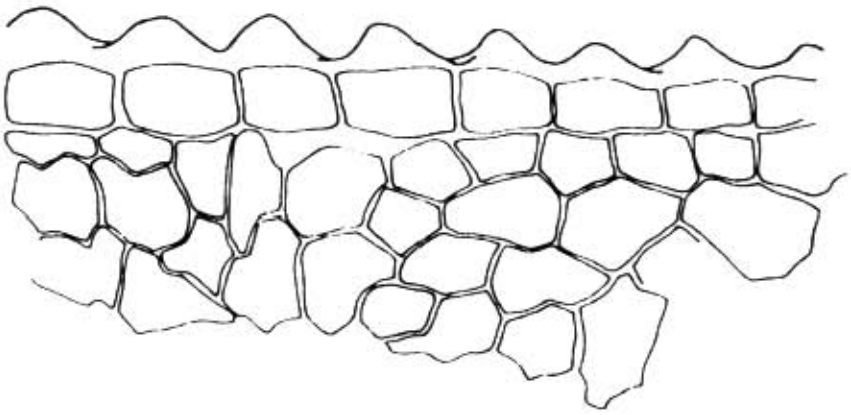
Polygonal epidermal cells.

≅0.25mm

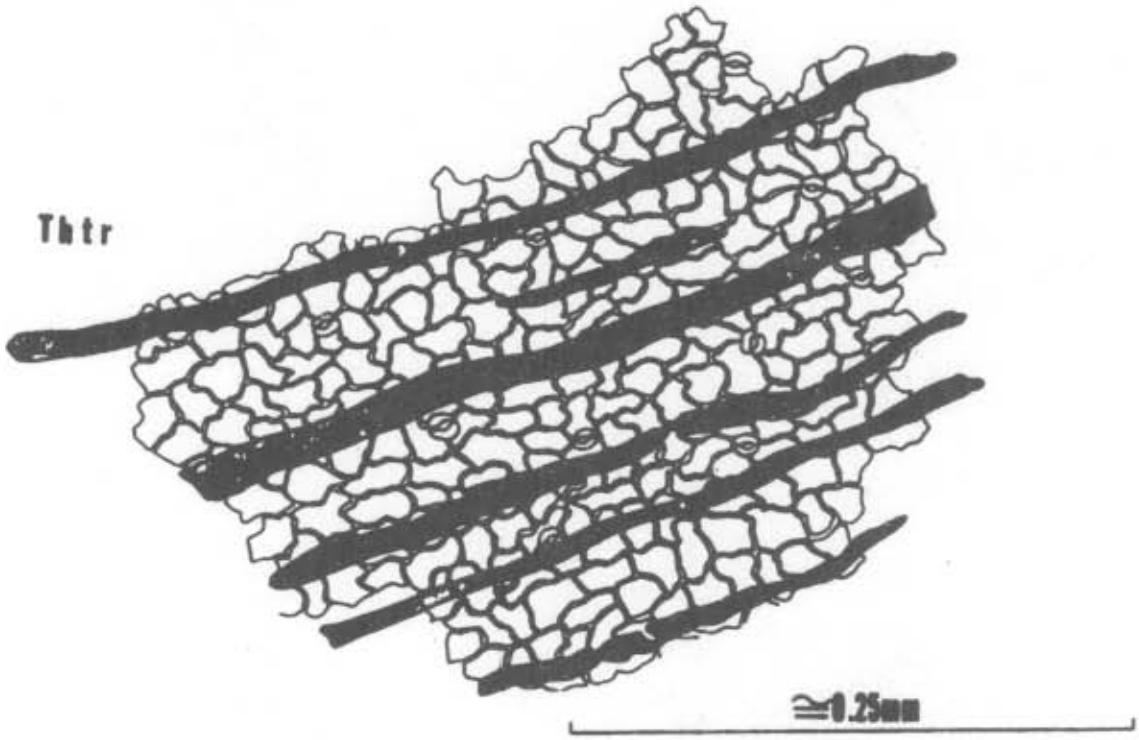
Caro

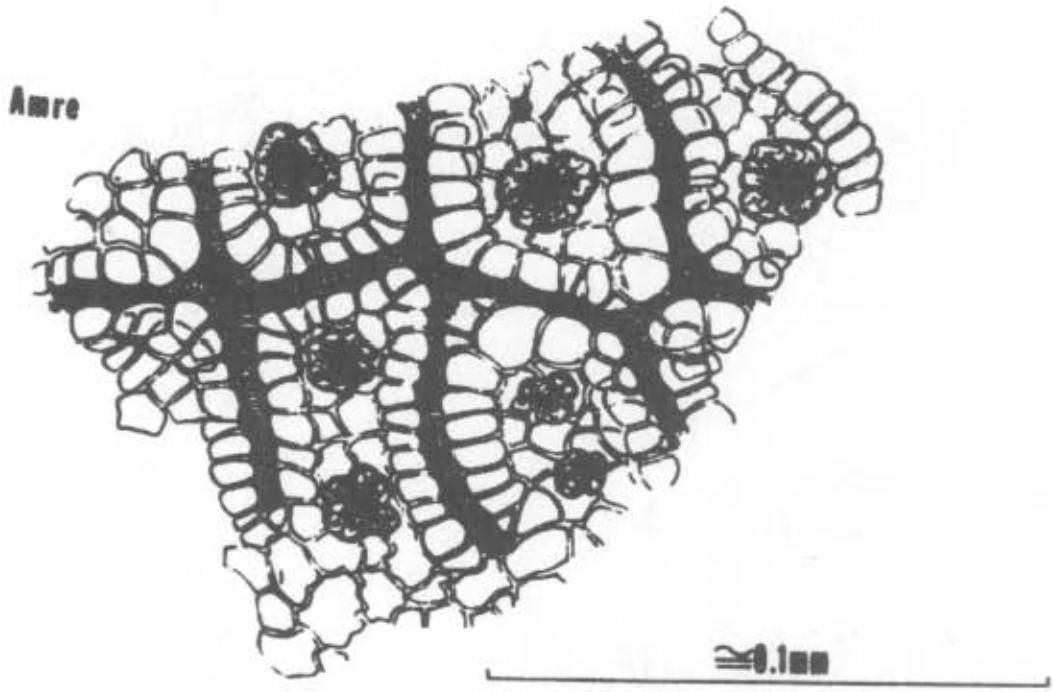


Pogl

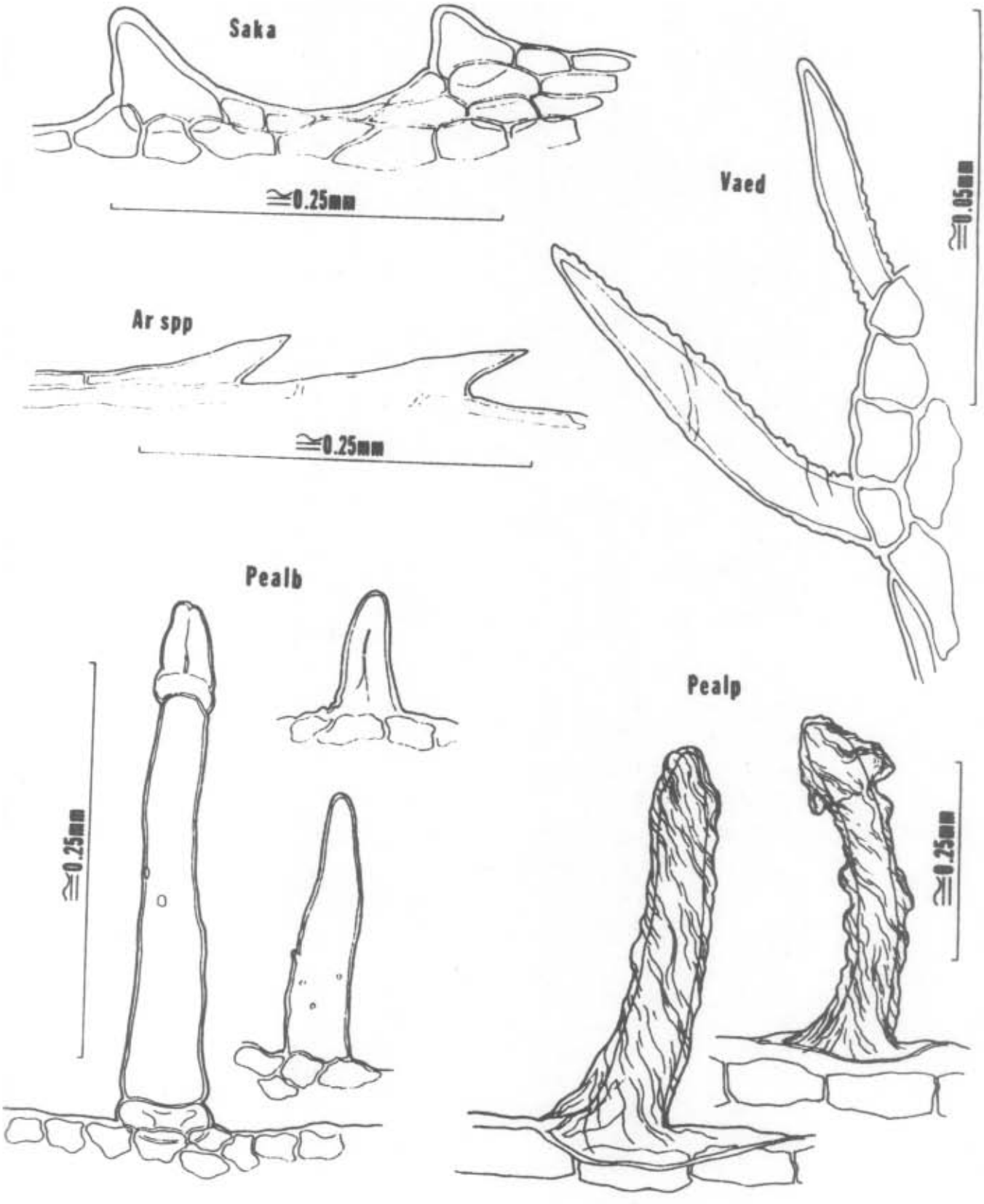


Polygonal epidermal cells. Note dotty cell wall of CARO.

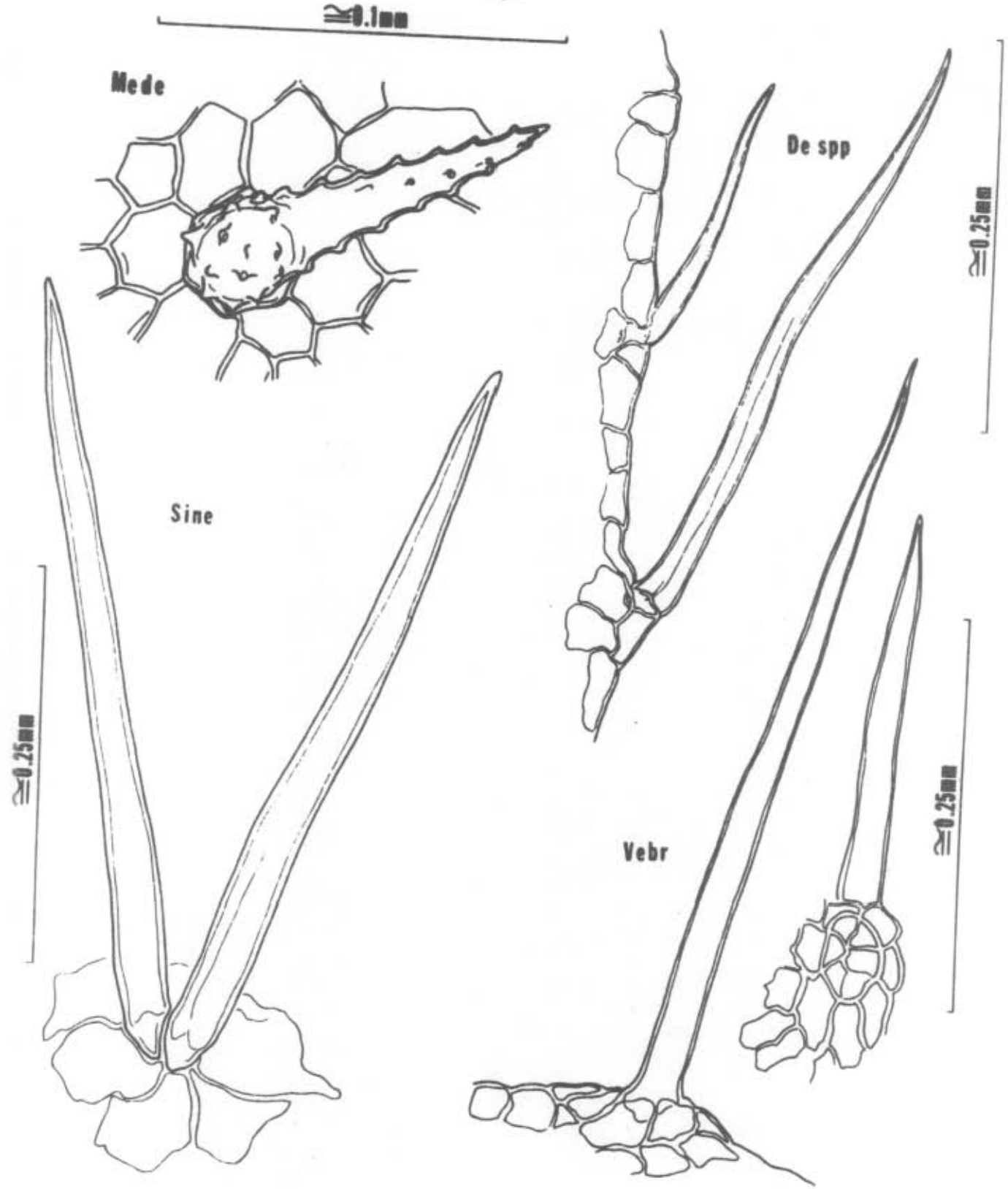




Epidermal cells with palasade-like appearance. Similar species are KOSC, and CHAL.



Unicellular, short trichomes. Species with trichomes very similar to ASKA are *Nuaincon divaricatum* and *Cymoptrus montanus*. *Lepidium densiflorum* and *Viola nuttallii* also have short unicellular trichomes. PEALB is a good example of a glandular trichome. Note wrinkled appearance of PEALP trichome.



Unicellular, rigid, elongated trichomes with pointed tip. Species with trichomes similar to DE SPP are *Ranunculus cymbalaria*, *Aquilegia oleyantula*, GECI, and GEFR. Note rosette attachment on SINE.