PRODUCTIDINA

C. H. C. BRUNTON,[1] S. S. LAZAREV,[2] R. E. GRANT,[3] and JIN YU-GAN[4]

[[1]formerly of the Natural History Museum, London; [2]Palaeontological Institute, Moscow; [3]deceased; and [4]Nanjing Institute of Geology and Palaeontology]

Suborder PRODUCTIDINA Waagen, 1883

[*nom. correct.* MUIR-WOOD, 1965b, p. 448, *pro* suborder Productacea WAAGEN, 1883, p. 447; *sensu* LAZAREV, 1990, p. 77]

Productides lacking interareas or with ginglymus only; toothed articulation absent after uppermost Devonian; cardinal process directed posteriorly or posterodorsally, not ventrally; brachial ridges commonly reniform, confined. [This group comprises the more characteristic productides that normally lived unattached on relatively soft substrates, stabilized by their straight or gently curved spines. There is a tendency within each superfamily for stratigraphically older representatives to have shallow corpus cavities that became deep in younger taxa. Trails may be long but lack elaboration, other than for rare anteromedian plication.] *Lower Devonian (Pragian)–Upper Permian (Changhsingian), ?Lower Triassic.*

Superfamily PRODUCTOIDEA Gray, 1840

[*nom. transl.* MAILLIEUX, 1941, p. 7, *ex* Productidae GRAY, 1840, p. 151]

Productidines with long trails, other than in early forms; ornamentation diverse, commonly ribbed, spines may be absent from near ventral hinge, otherwise widely to closely spaced; dorsal spines in some. *Lower Devonian (Emsian)–Upper Permian (Changhsingian), ?Lower Triassic.*

Family PRODUCTELLIDAE Schuchert, 1929

[*nom. transl.* MUIR-WOOD & COOPER, 1960, p. 145, *ex* Productellinae SCHUCHERT in SCHUCHERT & LEVENE, 1929, p. 17]

Shell small to medium sized; dorsal corpus concave, or rarely, only slightly concave; ribbing absent from beak or totally; spines varied, commonly on ventral valve only, commonly absent from hinge region; corpus cavity shallow, or rarely, deep in Carboniferous or Permian; teeth absent after uppermost Devonian; lateral ridges appearing in lower Tournaisian. *Lower Devonian (Emsian)–Upper Permian (Changhsingian), ?Lower Triassic).*

Subfamily PRODUCTELLINAE Schuchert, 1929

[Productellinae SCHUCHERT in SCHUCHERT & LEVENE, 1929, p. 17]

Ribs rarely developed, then only anteriorly; spines evenly distributed over ventral valve only; corpus shallow; teeth present; lateral ridges, ear baffles lacking; cardinal process lobes divergent, V-shaped dorsally, with pit; dorsal adductor scars commonly nondendritic. *Lower Devonian (Emsian)–Upper Devonian (Famennian).*

Productella HALL, 1867c, p. 153 [**Productus subaculeatus* MURCHISON, 1840, p. 255; SD OEHLERT, 1887b, p. 1279]. Width 10 to 20 mm; concavoconvex, with spines evenly distributed on ventral valve only, spine bases commonly not elongate; rugae weak posterolaterally, no ribbing. *Middle Devonian (Givetian)–Upper Devonian (Frasnian, ?Famennian):* Eurasia.——FIG. 278,*1a–e.* **P. subaculeata* (MURCHISON), upper Frasnian, France (Boulonnais); *a–d,* shell viewed posteriorly, laterally, ventrally, dorsally, ×2; *e,* dorsal valve interior, ×3 (Muir-Wood & Cooper, 1960).

Chattertonia JOHNSON, 1976, p. 789 [**Spinulicosta campbelli* CHATTERTON, 1973, p. 78; OD]. Similar to *Spinulicosta,* but with anderidia. *Lower Devonian (Emsian):* Australia.——FIG. 278,*2a–f.* **C. campbelli* (CHATTERTON), Emsian, New South Wales; *a,b,* holotype, viewed ventrally, dorsally, ANU 18950, ×3 (new); *c,* ventral valve lateral view, ×3; *d,* ventral valve exterior, ×2.2; *e,* ventral valve interior showing teeth, ×3; *f,* dorsal valve interior showing anderidia, *arrow,* ×4 (Chatterton, 1973).

Helaspis IMBRIE, 1959, p. 400 [**H. luma;* OD]. Resembles *Spinulicosta,* but exagerated elongate spine bases simulate ribs posteriorly, ribbed anteriorly. *Middle Devonian (Givetian):* North America.——FIG. 278,*3a–c.* **H. luma,* Givetian, Michigan; *a,b,* ventral, dorsal exteriors of shell, ×2; *c,* dorsal valve interior, ×2 (Imbrie, 1959).

Sinoproductella WANG, 1955b, p. 349 [**Productella hemispherica* TIEN, 1938, p. 19; OD]. Poorly known; gently concavoconvex with short trail, shallow corpus; ?short interareas or ginglymus; spines long on ears, low angled on rest of ventral valve, rugae weak dorsally, plus dimples; ?teeth. *upper Upper Devonian (Famennian):* China.——FIG.

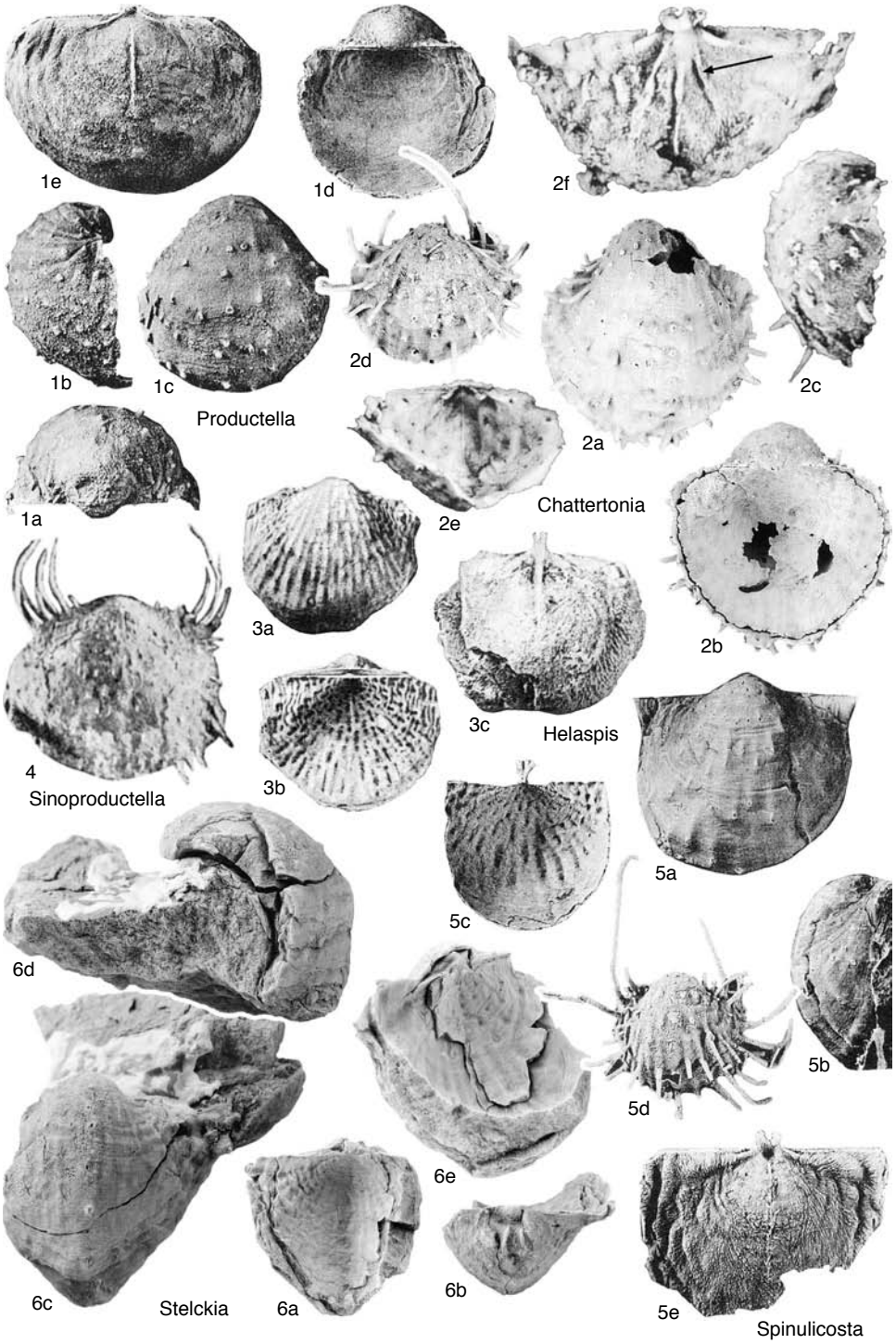

FIG. 278. Productellidae (p. 424–426).

278,*4. *S. hemispherica* (Tien), Famennian, Hsiknangshan Limestone, Hunan; ventral valve exterior, ×1 (Wang, 1955b).

Spinulicosta Nalivkin, 1937, p. 49 [**Productus spinulicostus* Hall, 1857, p. 173, OD]. Small; outline subrounded, strongly concavoconvex profile; weakly lamellose, spines as *Productella,* but with elongate spine ridges posterior to spines, ribbing anteriorly; dorsal valve dimpled. *Lower Devonian–Middle Devonian (Eifelian):* North America, Europe, Australia, ?Asia.——Fig. 278,*5a,b. *S. spinulicosta* (Hall), Eifelian, New York; *a,b,* lectotype, ventral valve exterior, lateral views, AMNH 4377a, ×2 (Muir-Wood & Cooper, 1960).——Fig. 278,*5c. S.* sp. cf. *S. spinulicosta* (Hall), Lower Devonian, Ohio; dorsal valve exterior, ×2 (Muir-Wood & Cooper, 1960).——Fig. 278,*5d,e. S.* sp. cf. *S. navicella* (Hall), Middle Devonian, Nevada; *d,* silicified ventral valve exterior, ×2; *e,* incomplete silicified dorsal valve interior, ×3 (Muir-Wood & Cooper, 1960).

Stelckia Crickmay, 1963, p. 21 [**S. galearius;* OD]. Poorly known; outline semicircular to subtriangular; highly arched medianly; ears flat; radial ridges faint, possibly spine bases; rugae on ears, weak on venter, dorsal valve; spines at ears, medianly, recumbent on venter. *Middle Devonian (Givetian):* Canada.——Fig. 278,*6a–e. *S. galearius,* Givetian, Ramparts Formation, Northwest Territories; *a,b,* holotype, incomplete corpus viewed dorsally, posteriorly, showing paired dorsal ridges, PRI 27111, ×1; *c,d,* ventral, lateral views of incomplete specimen, ×1.5; *e,* dorsolateral view of posteromedian region, ×2 (new).

Subfamily PRODUCTININAE Muir-Wood & Cooper, 1960

[Productininae Muir-Wood & Cooper, 1960, p. 181]

Wide-hinged productellids commonly ribbed, especially ventrally; few spines on ventral valve only, absent from hinge region; corpus cavity shallow, except some Paramarginiferini; brachial ridges, where present, with anterior lobe axes directed anteromedianly. *Upper Devonian (Famennian)–Upper Permian (Changhsingian), ?Lower Triassic.*

Tribe PRODUCTININI Muir-Wood & Cooper, 1960

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 926, *ex* Productininae Muir-Wood & Cooper, 1960, p. 181]

Ribbing on ventral valve, concentric lamellae prominent on dorsal valve; ventral profile an ideal spiral; no sulcus; brachial ridges unknown. *Upper Devonian (Famennian)–Lower Carboniferous (Asbian).*

Productina Sutton, 1938, p. 551 [**Productus sampsoni* Weller, 1909, p. 300; OD]. Small; subrounded outline with small ears, strongly concavoconvex with inflated umbo; ribbing regular, relatively fine, interrupted anteriorly by lamellae, especially dorsally. *Upper Devonian–Lower Carboniferous (lower Hastarian):* North America, Europe, Australia, ?northern Africa.——Fig. 279,*1a–e. *P. sampsoni* (Weller), Hastarian; *a,b,* ventral valve viewed ventrally, laterally, Texas, ×2; *c,* ventral valve viewed posteriorly, Texas, ×2; *d,e,* dorsal view of shell, dorsal valve interior, Caballero Formation, New Mexico, ×3 (Muir-Wood & Cooper, 1960).

Argentiproductus Cooper & Muir-Wood, 1951, p. 195, *nom. nov. pro Thomasella* Paul, 1942, p. 191, *non* Fredericks, 1928 [**Producta margaritacea* Phillips, 1836, p. 215; OD] [=*Thomasia* Fredericks, 1928, p. 783, *non* Poche, 1908, *nec* Rüebsaamen, 1910, *nec* Wilson, 1910, *nec* Lambert, 1918; *Thomasina* Paeckelmann, 1931, p. 181, *non* Newstead & Carter, 1911]. Transverse posteriorly; ribbing wide, flattened, branching, slightly lamellose, few ventral spines only. *Lower Carboniferous (Viséan):* Europe, northern Africa.——Fig. 279,*2a–f. *A. margaritacea* (Phillips), Asbian; *a,* neotype, ventral valve exterior, north Wales, BMNH BB 13616, selected by Brunton & Mundy, 1993, ×1; *b,c,* ventral, dorsal views of shell, silicified specimens, Fermanagh, British Isles, ×1.5; *d,* ventral view of young valve with median spine, silicified specimen, Fermanagh, ×1.5; *e,* ventral valve interior, silicified specimen, Fermanagh, ×2.5; *f,* dorsal valve interior, silicified specimen, Fermanagh, ×1.5 (new).

Dorsirugatia Lazarev in Lazarev & Suur'suren, 1992, p. 63 [**D. tsagankhalgensis;* OD]. Wide ears; weak ventral ribbing; row of three spines on each flank; dorsal lamellae plus weak anterior ribbing. *Upper Devonian (upper Famennian):* Mongolia.——Fig. 279,*3a–d. *D. tsagankhalgensis,* uppermost Famennian, Gobi Altai; *a,* holotype, viewed ventrally, PIN 3385/1523, ×3; *b–d,* ventral valve viewed anteroventrally, posteriorly, laterally, ×3 (Brunton & Mundy, 1993).

Productellina Reed, 1943, p. 99 [**Productus (Productellina) fremingtonensis;* OD]. Ears small; ventral valve only ribbed, dorsal valve lamellose; possibly only single pair of ventral flank spines. *Upper Devonian (Famennian)–Lower Carboniferous (lower Tournaisian):* southern Britain.——Fig. 279,*4a–d. *P. fremingtonensis,* lower Tournaisian, Pilton Beds, Devon; *a,b,* holotype, dorsal valve external mold, latex replica, OUM E287, ×2; *c,d,* ventral valve internal mold viewed ventrally, laterally, note spine base, *arrowed,* ×2 (new).

Tribe CHONETELLINI Licharew, 1960

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 926, *ex* Chonetellidae Licharew in Sarytcheva, Licharew, & Sokolskaja, 1960, p. 226] [=Haydenellinae Jing & Hu, 1978, p. 113]

Outline subtriangular, may have ginglymus; lateral profile deeply concavoconvex

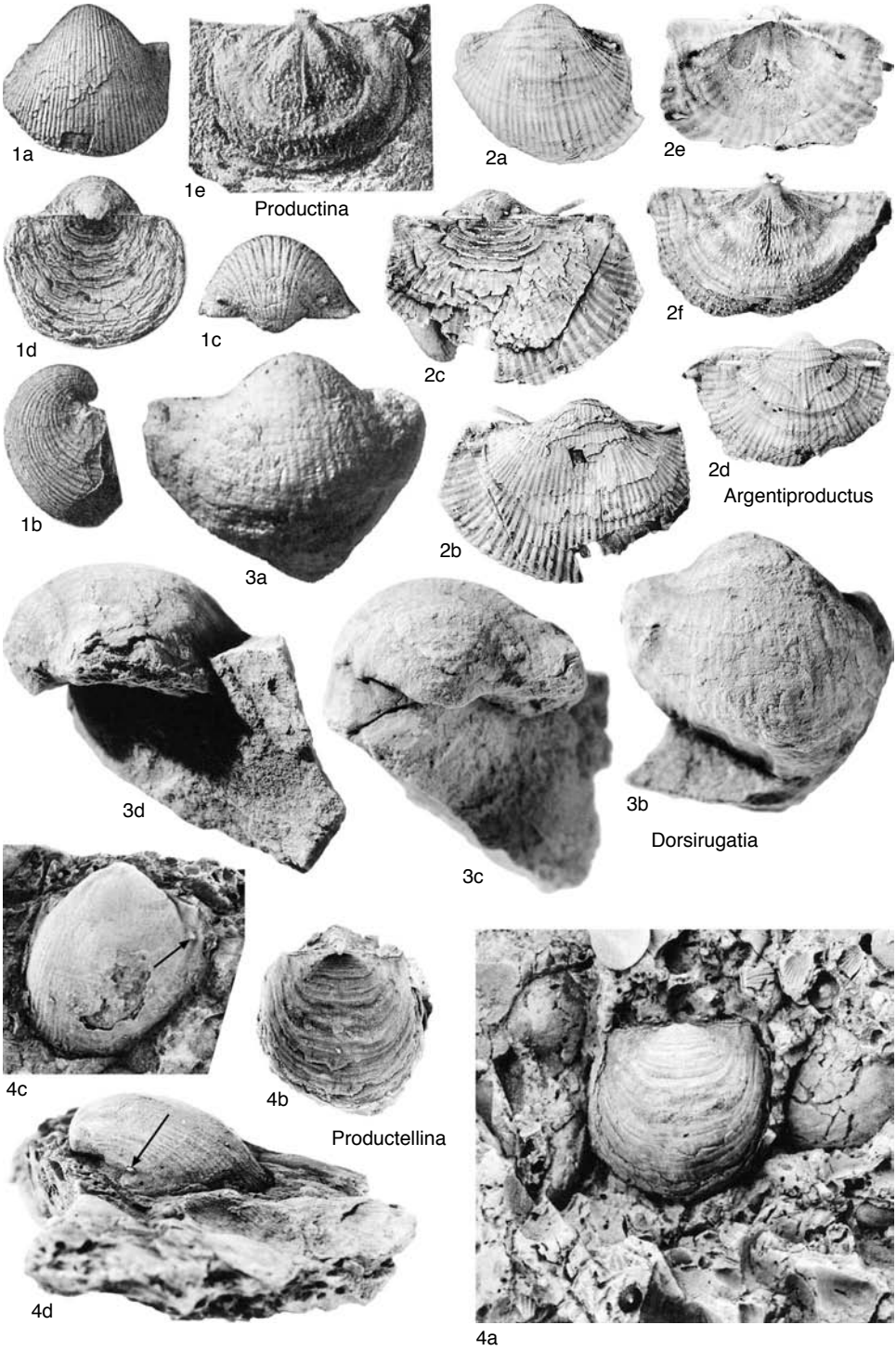

FIG. 279. Productellidae (p. 426).

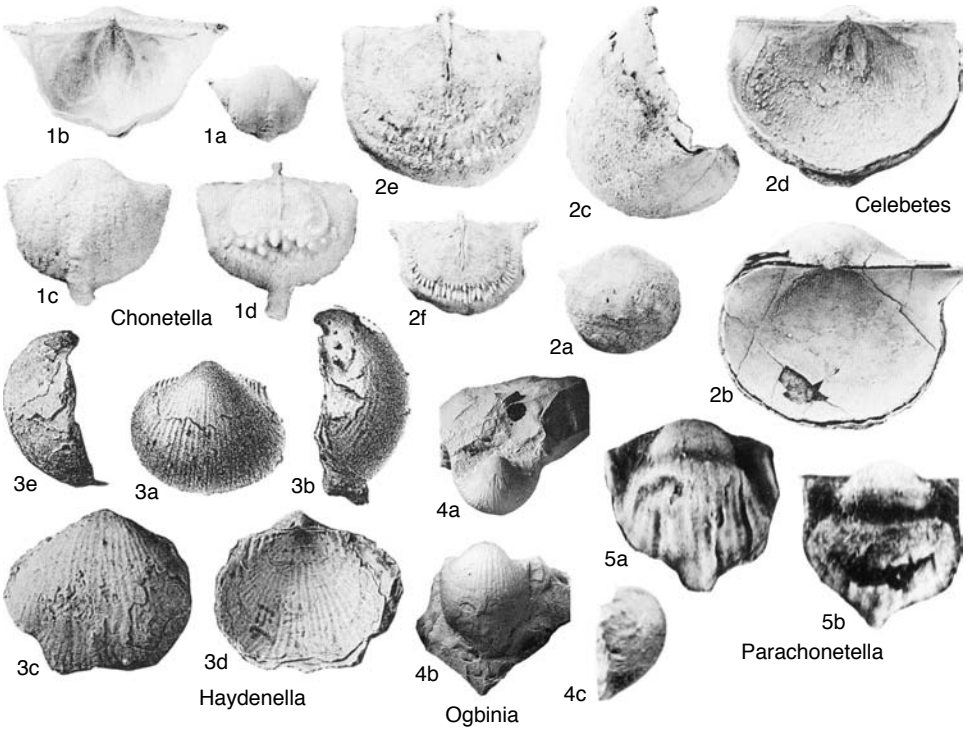

FIG. 280. Productellidae (p. 428–429).

with shallow corpus cavity; ribbing weak or absent; commonly nasute, with spines only flanking umbo. *Lower Permian (Artinskian)–Upper Permian (Changhsingian).*

Chonetella WAAGEN, 1884, p. 613, 657, *non Chonetella* KROTOW, 1885, p. 274, =*Chonetina* KROTOW, 1888, p. 500 [**C. nasuta;* OD]. Subcircular to transverse chonetiform, strongly nasute outline; ventral ginglymus; ribbing absent or weak; spines extend posterolaterally from hinge line, ?absent from corpus; cardinal process long, but narrow; lateral ridges divergent from hinge, long brachial ridges bordered anteriorly by strong endospines. *upper Lower Permian (Kungurian)–Upper Permian (Capitanian):* Pakistan (Salt Range).——FIG. 280,*1a–d.* **C. nasuta,* Permian, Kalabagh member, Khisor Range; *a,* ventral valve exterior, ×1; *b,* ventral valve interior, ×2; *c,* ventral valve exterior, ×2; *d,* dorsal valve interior, ×2 (Grant, 1976).

Celebetes GRANT, 1976, p. 137 [**C. gymnus;* OD]. Concavoconvex profile with weak geniculation; ribbing absent, concentric ornament weak or absent; spines few near hinge, few or absent elsewhere; anterior margin commonly not nasute; cardinal process narrow to trifid with short shaft; tubercles widespread, endospines at anterior margin of visceral disk. *Lower Permian (Artinskian):* Thailand.——FIG. 280,*2a–f.* **C. gymnus,* Artinskian, Phangnga; *a,* holotype, viewed ventrally, ×1; *b,c,* holotype, viewed dorsally, laterally, USNM 212444, ×2; *d,* ventral valve interior, ×2; *e,* dorsal valve interior, ×2; *f,* dorsal valve interior, ×1 (Grant, 1976).

Haydenella REED, 1944, p. 78 [**Productus kiangsiensis* KAYSER, 1883, p. 185; OD] [=*Striatospica* WATERHOUSE, 1975, p. 11 (type, *Striatifera kayseri* CHAO, 1927b, pl. 13, fig. 9; OD)]. Smaller medium-sized corpus with short simple trails, broad outline; short ginglymus common; ribbing weak, absent at umbos; rugae only on ears; spines separate corpus from posterior ear regions, thin spines scattered on ventral corpus; ventral diductor scars prominent; cardinal process dorsally trifid; lateral ridges weak, no marginal ridges. *upper Lower Permian (Roadian)–Upper Permian (Tatarian):* China, Asia, Transcaucasia.——FIG. 280,*3a–e.* **H. kiangsiensis* (KAYSER); *a,b,* ventral valve exterior, lateral view of shell showing flank spines, Permian, Jiangxi, ×1; *c–e,* ventral, dorsal, lateral views of shell, middle *Productus* Limestone, Salt Range, Pakistan, ×1 (Muir-Wood & Cooper, 1960).

Ogbinia SARYTCHEVA in SARYTCHEVA & SOKOLSKAYA, 1965, p. 229 [**O. dzhagrensis;* OD]. Small, around 10 mm wide, elongate outline; ginglymus; ribbing low, lacking rugae; spines in row near hinge only;

cardinal process unifid, supported by shell thickening anteriorly; median septum short. *upper Lower Permian (Roadian):* Transcaucasus.——Fig. 280,*4a–c.* **O. dzhagrensis,* Ufimian, Transcaucasus; holotype, viewed posteriorly, ventrally, laterally, PIN 2071/65, ×1 (Sarytcheva & Sokolskaya, 1965).

?Parachonetella Liao, 1980, p. 260 [**P. zhongyingensis;* OD]. Resembles *Chonetella,* but differs in having irregular ribs on trail, ventral cincture at corpus margin. *upper Upper Permian (Changhsingian):* China.——Fig. 280,*5a,b.* **P. zhongyingensis,* Changhsingian, Guizhou; *a,* holotype, anteroventral view, NIGP 43650, ×2; *b,* anteroventral view of another specimen, ×2 (new).

Planihaydenella Chang, 1987, p. 757[764] [**P. anqingensis;* OD]. Poorly known, possible synonym of *Haydenella,* but ribbing reportedly well developed. *?Upper Permian:* China.

Tribe PARAMARGINIFERINI Lazarev, 1986

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 926, *ex* Paramarginiferinae Lazarev, 1986c, p. 23]

Radial ribbing and, in some, posteriorly reticulate; ventral profile distorted, ventral trail (when present) commonly becoming anteriorly nasute; ventral marginal ridges commonly developed. *Lower Carboniferous (Viséan)–Upper Permian (Changhsingian), ?Lower Triassic.*

Paramarginifera Fredericks, 1916, p. 61 [**Marginifera clarkei* Chernyschev, 1902, p. 328; OD]. Medium size with pentagonal outline; profile concavoconvex, long trail with broadly nasute extension; median sulcus originates at umbo; ribbing complete, rugae weak on disks; six spines symmetrically disposed on ears, flanks, venter; cincture bordering ventral corpus; interior unknown. *Lower Permian (Asselian–Artinskian):* Ural Mountains, Inner Mongolia, northern China.——Fig. 281,*1a–d.* **P. clarkei* (Tschernyschew), Permian, *Schwagerina* Limestone, Ural Mountains; *a,b,* anteroventral view, anterior view, ×1; *c,d,* posteroventral view, lateral view, ×1 (Muir-Wood & Cooper, 1960).

Alitaria Cooper & Muir-Wood, 1967, p. 808, *nom. nov. pro Alifera* Muir-Wood & Cooper, 1960, p. 207 (type, *Productus expansus* de Koninck, 1842, p. 159, *non* Pander, 1830) [**Alifera konincki* Muir-Wood & Cooper, 1960, p. 208; OD]. Transverse outline with large strongly differentiated ears; disks reticulate, commonly two pairs of thick halteroid spines on flanks; strong ventral marginal ridges. *Lower Carboniferous (Viséan):* Europe, northern Africa, northern Asia.——Fig. 281,*2a–f.* **A. konincki* (Muir-Wood & Cooper), Viséan, Visé, Belgium; *a,* oblique lateral view of internal mold showing marginal ridge, ×2; *b,c,* ventral view of internal mold, replica of its dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960); *d–f,* anterior, posterior, lateral views of ventral valve exterior, ×1.5 (new).

Bibatiola Grant, 1976, p. 136 [**B. costata;* OD]. Outline broadly triangular with nasute anterior margin; deeply concavoconvex; ribbing originates posteriorly on disks; spines few, two or three on each flank, up to six on venter; cardinal process trifid, sessile; lateral ridges extend weakly to separate ears; endospines short, few. *Lower Permian (Artinskian):* Thailand.——Fig. 281,*3a–e.* **B. costata,* Artinskian, Ko Muk; *a–c,* holotype, viewed ventrally, dorsally, laterally, USNM 212423, ×2; *d,e,* dorsal valve interior, viewed laterally, ×2 (Grant, 1976).

Bothrionia Cooper & Grant, 1975, p. 984 [**B. nasuta;* OD]. Outline nasute; median ribs may be lacking at sulcus, on trail may branch anterior to spine bases; spines few, one large spine on each ear, others over ventral valve; posterior sulcus becoming nasute anteriorly at adult margin; ventral ear baffles continued anteriorly to form low ridge around corpus; cardinal process sessile, trifid; median septum short, thin; endospines numerous, long. *Permian (Wordian):* USA.——Fig. 281,*4a–e.* **B. nasuta,* Permian, Word Formation, Texas; *a–c,* holotype, viewed ventrally, dorsally, laterally, USNM 149637a, ×1; *d,* ventral valve interior, ×2; *e,* dorsal valve interior, ×3 (Cooper & Grant, 1975).

Cathaysia Ching in Wang, Ching, & Fang, 1966, p. 327 [**Productus chonetoides* Chao, 1927b, p. 62; OD]. Small with transverse to quadrate outline, concavoconvex profile; ears distinct, sulcus shallow or absent; ribbing branched, rugae on ears, near hinge only; single large spine on each ear, one or two on each side of trail; ventral muscle scars smooth with slightly excavated adductor scars, prostrate endospines; dorsal interior with numerous endospines. *Permian (Artinskian–Changhsingian), Lower Triassic (?lower Scythian):* southern China, Caucasus.——Fig. 282,*1a–d.* **C. chonetoides* (Chao), Permian Coal Series, Jiangsu Province; *a,b,* ventral views of two incomplete specimens, Changhsingian, Zhejiang Province, ×1 (new); *c,* replica of dorsal valve interior, Fujian Province, ×2; *d,* ventral valve exterior, ×2 (Xu & Grant, 1994).

Cymoproductus Xu, 1987, p. 227 [**C. callicostella;* OD]. Poorly known; medium size, transverse with hinge equal to maximum width; ventral disk weakly convex, geniculate with short trail; ribbing fine, ears with irregular rugae only; spines strong, in rows separating ears; interiors unknown. *Upper Permian (Changhsingian):* China.——Fig. 282,*6a,b.* **C. callicostella,* Changhsingian, China; *a,* ventral valve exterior, ×1; *b,* incomplete dorsal valve exterior with dimples opposite ventral spine positions, ×1 (Xu, 1987).

Eomarginiferina Brunton, 1966, p. 229 [**Eomarginifera (E.) trispina;* OD]. Small, around 10 mm wide; ventral profile with tight spiral, trail rarely slightly nasute; reticulate posteriorly, few (commonly three) thick symmetrical ventral spines; corpus relatively deep; no median sulcus; no anterior ventral

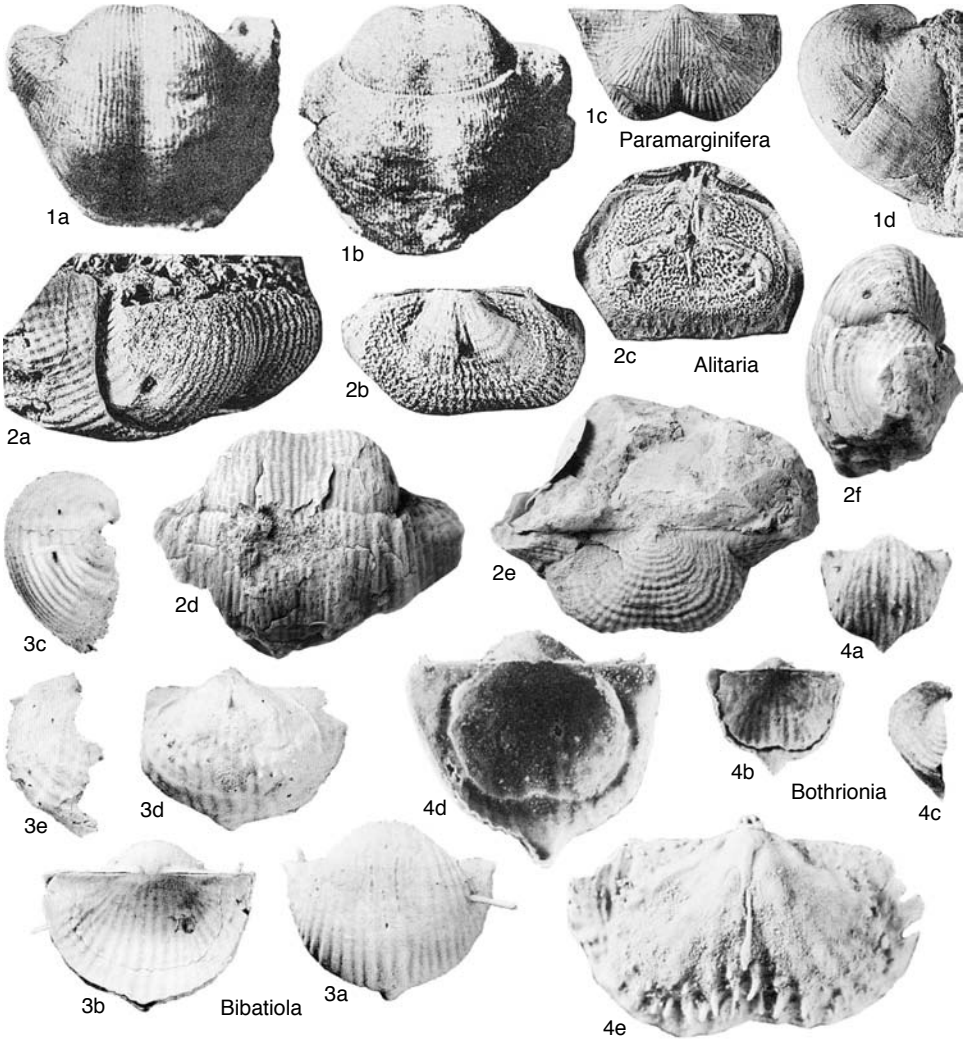

FIG. 281. Productellidae (p. 429).

marginal ridges. *Carboniferous (Viséan, ?lower Moscovian):* Europe, ?China.——FIG. 282,*2a–h.* **E. trispina* (BRUNTON), Asbian, Fermanagh, British Isles, silicified specimens; *a,* holotype viewed dorsally, showing position of ear baffles, BMNH BB 52890, ×4; *b–d,* ventral valve viewed ventrally, laterally, internally, showing median spine cavity, *arrow,* ×3; *e,f,* dorsal valve interior viewed ventrally, posteroventrally, ×4; *g,* young ventral valve exterior with three major spines, ×3; *h,* juvenile ventral valve with pedicle sheath, ×15 (Brunton, 1966).

Huatangia LIAO & MENG, 1986, p. 78[91] [**H. sulcatifera;* OD]. Small transverse shell with narrow anterior sulcus; ribbing irregular on corpus, fine on trail; rugae strong posterolaterally on ventral valve, reticulate posteriorly on dorsal disk; ventral marginal ridge; cardinal process narrow (?unifid). *Upper Permian (Changhsingian):* China.——FIG. 282,*4a–d.* **H. sulcatifera,* Changhsingian, Hunan; *a,* holotype, lateral view, NIGP 74198, ×1; *b,* anteroventral view, NIGP 74198, ×2; *c,* ventral valve exterior, ×1; *d,* external mold of dorsal valve, ×1.5 (new).

?Paryphella LIAO in ZHAO & others, 1981, p. 53[83] [**Cathaysia sulcatifera* LIAO, 1980, p. 261; OD] [=*Spinoparyphella* LIANG, 1990, p. 11, *nom. nud.* (type, *S. zhinanensis;* OD)]. Small, widest at hinge with large flat ears; ginglymus short; dorsal disk weakly concave; ribbing simple, weak posteriorly; rugae strong on ears; two pairs of spines at hinge;

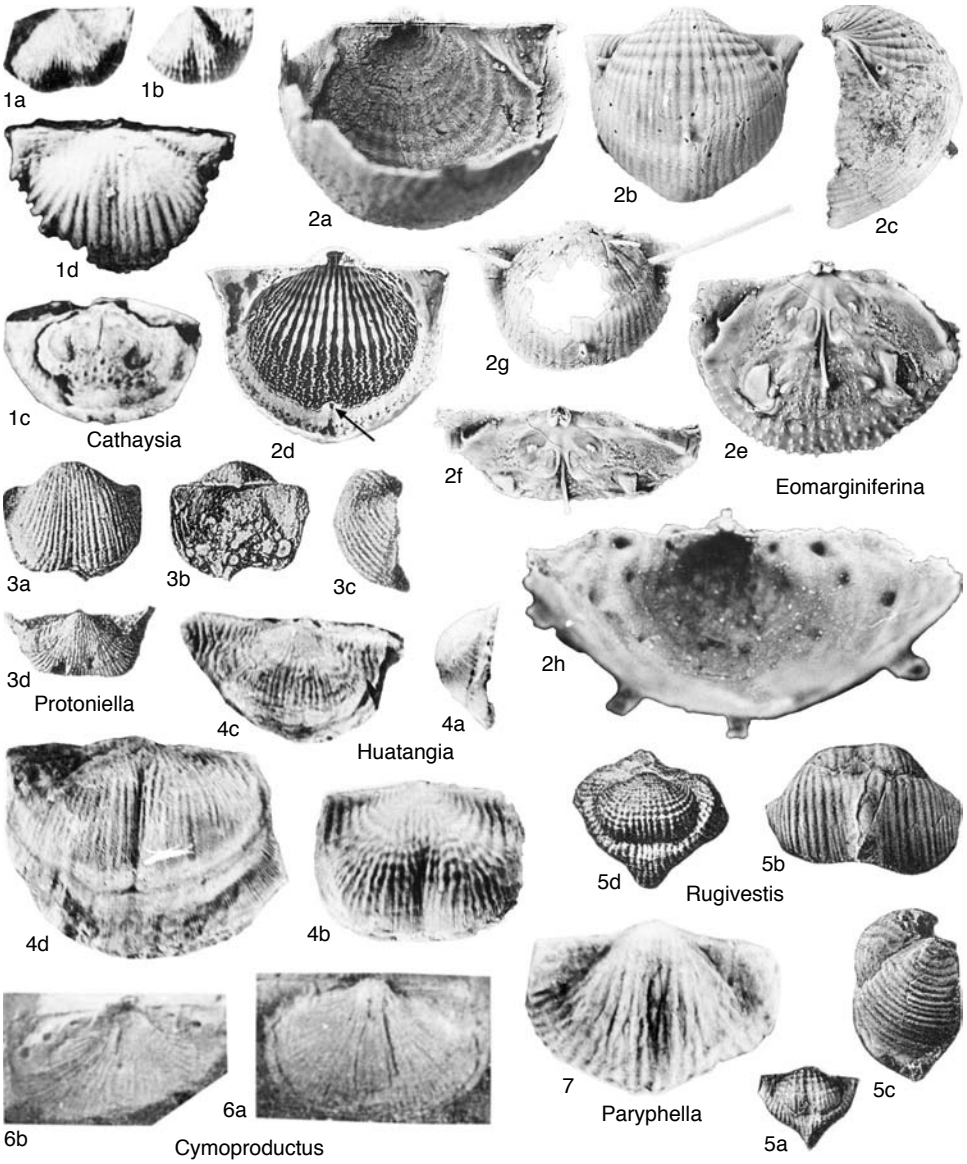

FIG. 282. Productellidae (p. 429–432).

cardinal process narrow, elongate; low median septum extending to midlength of valve. *upper Upper Permian (Changhsingian), ?Lower Triassic:* southern China.——FIG. 282,*7. *P. sulcatifera* (LIAO), upper Upper Permian, Guizhou; ventral valve exterior, ×3 (new).

?Protoniella BELL, 1929, p. 110 [**P. beedii;* OD]. Small; outline rounded, profile concavoconvex, slight median sulcus on ventral trail; ribbing starts near beak, bearing fine scattered spines ventrally; dorsal valve ribbed, weakly lamellose anterolaterally, no rugae; cardinal ridges, ear baffles. *Lower Carboniferous (upper Viséan–lower Serpukhovian):* central, eastern North America.——FIG. 282,*3a–d. **P. beedi,* Lower Carboniferous, upper Windsor, Nova Scotia; *a–c,* holotype, viewed ventrally, dorsally, laterally, GSC 7954d, ×1; *d,* posterior view of ventral valve, ×1 (Muir-Wood & Cooper, 1960).

Rugivestis MUIR-WOOD & COOPER, 1960, p. 235 [*?*Proboscidella carinata* MUIR-WOOD & COOPER in

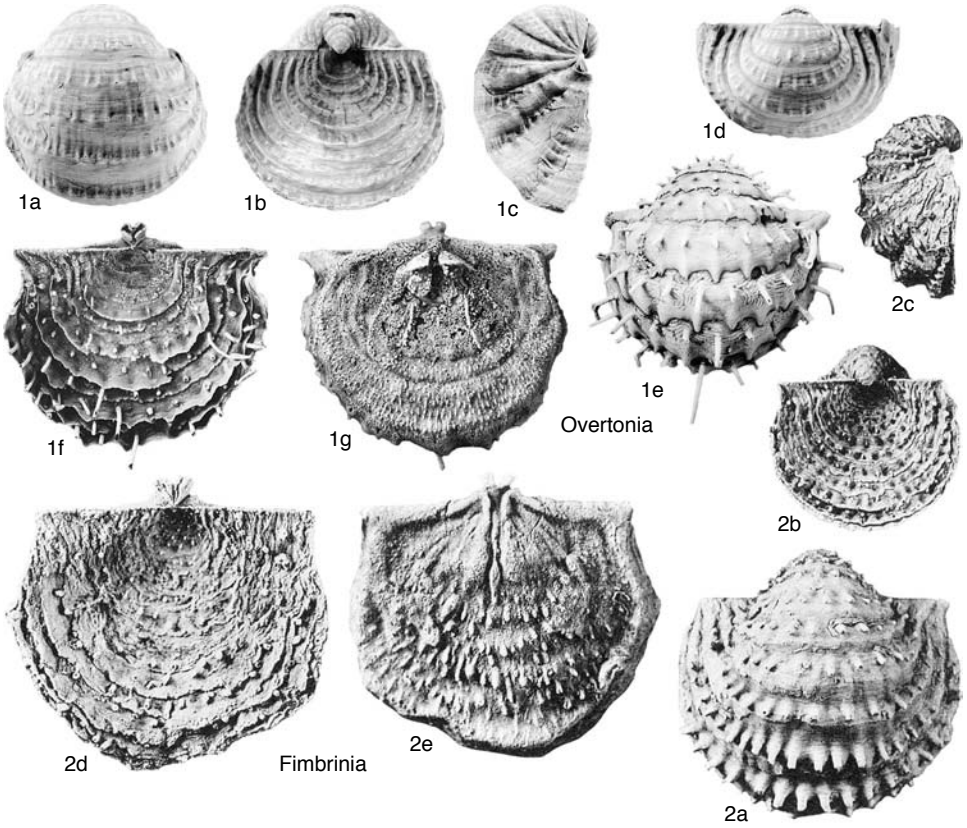

FIG. 283. Productellidae (p. 432–433).

COOPER, 1957, p. 36; OD]. Small, trigonal outline with trail folded into broad nasute extension; short flanges at start of trail continuous with ears; disks concavoconvex, reticulate; ribbing well developed on trails; spines few, symmetrically placed; marginal ridges in both valves. *Lower Permian (Asselian–Artinskian, ?Kungurian):* North America, Russia. ——FIG. 282,*5a–c.* **R. carinata* (MUIR-WOOD & COOPER), Permian, Coyote Butte Formation, Oregon; *a,* holotype, viewed ventrally, USNM 124156a, ×1; *b,c,* holotype, viewed anteriorly, laterally, USNM 124156a, ×2 (Muir-Wood & Cooper, 1960).——FIG. 282,*5d. R. kutorgae* (TSCHERNYSCHEW), Lower Permian, *Schwagerina* Limestone, southern Ural Mountains; ventral view, ×1 (Muir-Wood & Cooper, 1960).

Subfamily OVERTONIINAE Muir-Wood & Cooper, 1960

[Overtoniinae MUIR-WOOD & COOPER, 1960, p. 183] [=Avoniidae SARYTCHEVA in SARYTCHEVA, LICHAREW, & SOKOLSKAJA, 1960, p. 226, *partim*]

Ribs absent or rarely confined anteriorly on trails; spines scattered equally on both valves, but absent from ventral hinge; corpus depth varied. *Upper Devonian (upper Famennian)–Upper Permian (Tatarian).*

Tribe OVERTONIINI Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 926, *ex* Overtoniinae MUIR-WOOD & COOPER, 1960, p. 183]

Strong rounded rugae bearing spines; corpus cavity deep; dorsal adductor scars raised. *Lower Carboniferous (upper Viséan)–Lower Permian (Asselian).*

Overtonia THOMAS, 1914, p. 259 [**Producta fimbriata* J. DE C. SOWERBY, 1824 in 1823–1825, p. 85; OD]. Small to medium; ventral spines associated with rugae from crests, short prostrate spines at lamellose anterior margins; dorsal spines erect in bands between series of short trails; dorsal adductor platforms raised. *Lower Carboniferous (upper Viséan):* Europe, ?Asia, ?northern Africa.——FIG. 283,*1a–g.* **O. fimbriata* (J. DE C. SOWERBY); *a–d,* ventral, dorsal, lateral, posterior views of shell, Asbian, York-

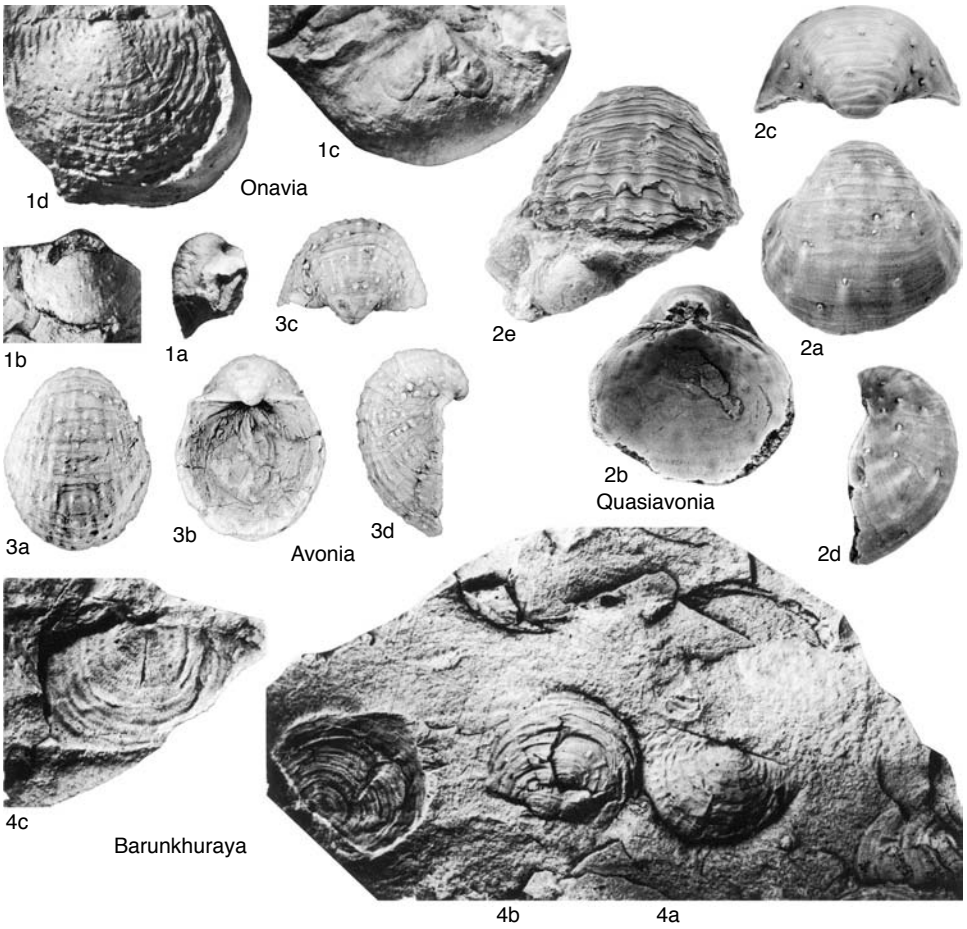

FIG. 284. Productellidae (p. 433–434).

shire, ×1 (new); *e–g,* ventral valve exterior, dorsal valve exterior, interior, silicified specimens, Fermanagh, ×2 (Brunton, 1966).

Fimbrinia COOPER, 1972, p. 450, *nom. nov. pro Fimbriaria* MUIR-WOOD & COOPER, 1960, p. 186, *non* FROELICH, 1802 [**Overtonia plummeri* KING, 1938, p. 276; OD]. Similar to *Overtonia* but small; spine bands single, from crests of rugae; dorsal adductor scars commonly not elevated. *Upper Carboniferous (Kasimovian)–Lower Permian (Asselian):* North America.——FIG. 283,*2a–e. *F. plummeri* (KING), Finnis Shale, Texas; *a,* ventral, ×3; *b,c,* dorsal, lateral views of shell, ×2; *d,e,* dorsal valve exterior, interior, ×4 (Muir-Wood & Cooper, 1960).

Tribe AVONIINI Sarytcheva, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 926, *ex* Avoniidae SARYTCHEVA in SARYTCHEVA, LICHAREW, & SOKOLSKAJA, 1960, p. 226]

Concentric ornament of broad irregular lamellose bands; ventral lateral profile an ideal spiral; corpus cavity shallow to moderate. *Upper Devonian (upper Famennian)–Lower Carboniferous (lower Serpukhovian).*

Avonia THOMAS, 1914, p. 259 [**Productus youngianus* DAVIDSON, 1860, p. 180; OD]. Outline somewhat elongate; concentric ornament of weak irregular lamellae, ribbing weak, only anteriorly; lateral ridges to inner side of ears. *Lower Carboniferous (Viséan–lower Serpukhovian):* Europe, Asia.——FIG. 284,*3a–d. *A. youngiana* (DAVIDSON), Brigantian, Stirlingshire; *a–d,* lectotype, viewed ventrally, dorsally, posteriorly, laterally, BMNH B 45680, ×1.5 (new).

Barunkhuraya LAZAREV in BRUNTON & LAZAREV, 1997, p. 385 [**B. indrengynensis;* OD]. Small, slightly wider than long; nongeniculate; rugae on both valves, slightly lamellose; spines ventral, with swollen bases, row near hinge; cardinal process pit; lateral ridges weak, very short, but strongly divergent. *Upper Devonian (upper Famennian):* Mongolia

(Indrengyn-Nuru Mountains).——Fig. 284,*4a–c.* **B. indrengynensis,* upper Famennian, Indrengyn-Nuru Mountains; *a,b,* slab showing holotype, dorsal valve external mold (right), ventral valve external mold (left), PIN N 3385/1104, ×2; *c,* dorsal valve internal mold, ×2 (Brunton & Lazarev, 1997).

Onavia Lazarev in Brunton & Lazarev, 1997, p. 387 [**O. barunkhurensis;* OD]. Small, nongeniculate; rugae, spines on both valves; lateral ridges very short, weak. *Lower Carboniferous (Tournaisian):* Mongolia.——Fig. 284,*1a–d.* **O. barunkhurensis,* Tournaisian, Khuren-Ula Mountains; *a,* holotype, viewed laterally, PIN N 3385/1358, ×1; *b,* ventral view of specimen with most of ventral valve missing, ×1; *c,* ventral valve internal mold, ×2; *d,* dorsal valve external mold, ×2 (Brunton & Lazarev, 1997).

Quasiavonia Brunton, 1966, p. 219 [**Productus aculeatus* J. Sowerby, 1814 in 1812–1815, p. 156; OD]. Ventral umbo inflated; both valves irregularly lamellose, spines with slightly swollen bases ventrally, fine dorsally; corpus cavity moderate. *Lower Carboniferous (Viséan):* Europe, western Asia, northern Africa.——Fig. 284,*2a–e.* **Q. aculeata* (J. Sowerby); *a–d,* lectotype, viewed ventrally, dorsally, posteriorly, laterally, Viséan, Derbyshire, BMNH B 60992, ×2; *e,* specimen viewed anteriorly, showing lamellae, Brigantian, Derbyshire, ×2 (new).

Tribe COSTISPINIFERINI Muir-Wood & Cooper, 1960

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 926, *ex* Costispiniferinae Muir-Wood & Cooper, 1960, p. 217] [=Tubersulculinae Waterhouse in Bamber & Waterhouse, 1971, p. 205]

Concentric ornament weak; ribbing may be present on trails; ventral profile geniculate, with shallow to deep corpus cavity. *Upper Carboniferous (Gzhelian)–Upper Permian (Tatarian).*

Costispinifera Muir-Wood & Cooper, 1960, p. 217 [**C. texana;* OD; =*Avonia walcottiana costata* R. E. King, 1931, p. 85]. Small, transverse corpus with geniculate profile, deep cavity, elongate trails; rugae irregular on posterior disks; ribbing developed on trails; spines evenly distributed over ventral valve, thinner on dorsal valve; cardinal process with short shaft; lateral ridges extend across ears; long endospines border brachial areas anteriorly and laterally. *upper Lower Permian (Roadian)–lower Upper Permian (lower Kazanian):* USA.——Fig. 285,*1a–f.* **C. texana,* Kazanian, Word Limestone, Texas; *a–d,* holotype, viewed anteriorly, posteriorly, dorsally, laterally, USNM 124150a, ×1; *e,* ventral valve partial interior, ×2; *f,* dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Comuquia Grant, 1976, p. 97 [**C. modesta;* OD]. Small, elongate ovate; concavoconvex profile with shallow corpus; ribbing absent, some growth lines prominent; spines evenly distributed on ventral valve, dorsal spines fine; cardinal process bilobed, weakly quadrifid; median ridge weak, short; brachial ridges not developed. *Lower Permian (Artinskian):* Thailand, Himalaya, northern Tibet.——Fig. 285,*2a–e.* **C. modesta,* Artinskian, Ko Muk, Thailand; *a–c,* holotype, ventral valve viewed ventrally, internally, laterally, USNM 212136, ×3; *d,* dorsal view of complete shell, ×3; *e,* young dorsal valve interior, ×3 (Grant, 1976).

Darlinuria Li & Gu, 1976, p. 245 [**D. liaoningensis;* OD]. Small, subcircular corpus outline with small, well-differentiated ears; ventral profile weakly convex; dorsal valve concave; corpus cavity shallow; spines prostrate, small, in groups on ears, scattered on disk, concentrically in broad bands anteriorly; dorsal spines reportedly few; interiors poorly known. *Upper Permian (Kazanian–Tatarian):* Inner Mongolia, China.——Fig. 285,*3a–e.* **D. liaoningensis,* Upper Permian, Liaoning Province; *a,b,* holotype, ventral, posterior views (with ventral valve uppermost), SIGM 7K20, ×2.5; *c,d,* ventral, lateral views of specimen, ×3; *e,* internal mold of ventral valve, ×2 (new).

Dorashamia Sarytcheva in Sarytcheva & Sokolskaya, 1965, p. 217 [**D. abichi;* OD]. Small chonetiform shell with thick-walled valves; ornament of weak rugae becoming lamellose anteriorly; spine row near hinge, rare thin spines over venter, three spines separate dorsal ears; cardinal process sessile, bilobed; lateral ridges separate ears, disappear anteriorly. *Upper Permian (upper Capitanian):* Transcaucasus, ?North Caucasus, Kashmir.——Fig. 285,*5a–d.* **D. abichi,* upper Capitanian, Transcaucasus; *a,b,* holotype viewed ventrally, dorsally, PIN 2072/42, ×4; *c,* holotype viewed laterally, PIN 2072/42, ×1; *d,* incomplete dorsal valve exterior, ×4 (Sarytcheva & Sokolskaya, 1965).

Dyschrestia Grant, 1976, p. 101 [**D. spodia;* OD]. Broadly subovate, widest near midlength; beak inflated; spines equally and widely scattered on ventral disk, thicker in groups on flanks and on concentric lamellae on trail; dorsal spines slender; lateral ridges extend to separate ears weakly; endospines numerous in broad band around brachial ridges. *Lower Permian (upper Artinskian):* Thailand, Western Australia, Indonesia.——Fig. 286,*1a–e.* **D. spodia,* upper Artinskian, Ko Muk, Thailand; *a–c,* holotype viewed ventrally, dorsally, laterally, USNM 212164, ×2; *d,* incomplete ventral valve interior, ×4; *e,* dorsal valve interior, ×2 (Grant, 1976).

Echinauriella Lazarev in Brunton & Lazarev, 1997, p. 387 [**Krotovia jisuensiformis* Sarytcheva in Sarytcheva & Sokolskaya, 1965, p. 216; OD]. Small, around 10 mm wide, strongly convex profile; spines fine posteriorly, densely distributed on both valves; plications incipient on trail; dorsal lateral ridges prominent, adductor scars narrow, elongate. *upper Lower Permian (Roadian)–Upper Permian (Kazanian):* Transcaucasus.——Fig. 285,*4a–d.* **E. jisuensiformis* (Sarytcheva), Roadian, River Vedi; *a,b,* holotype, viewed ventrally, laterally, PIN 2071/

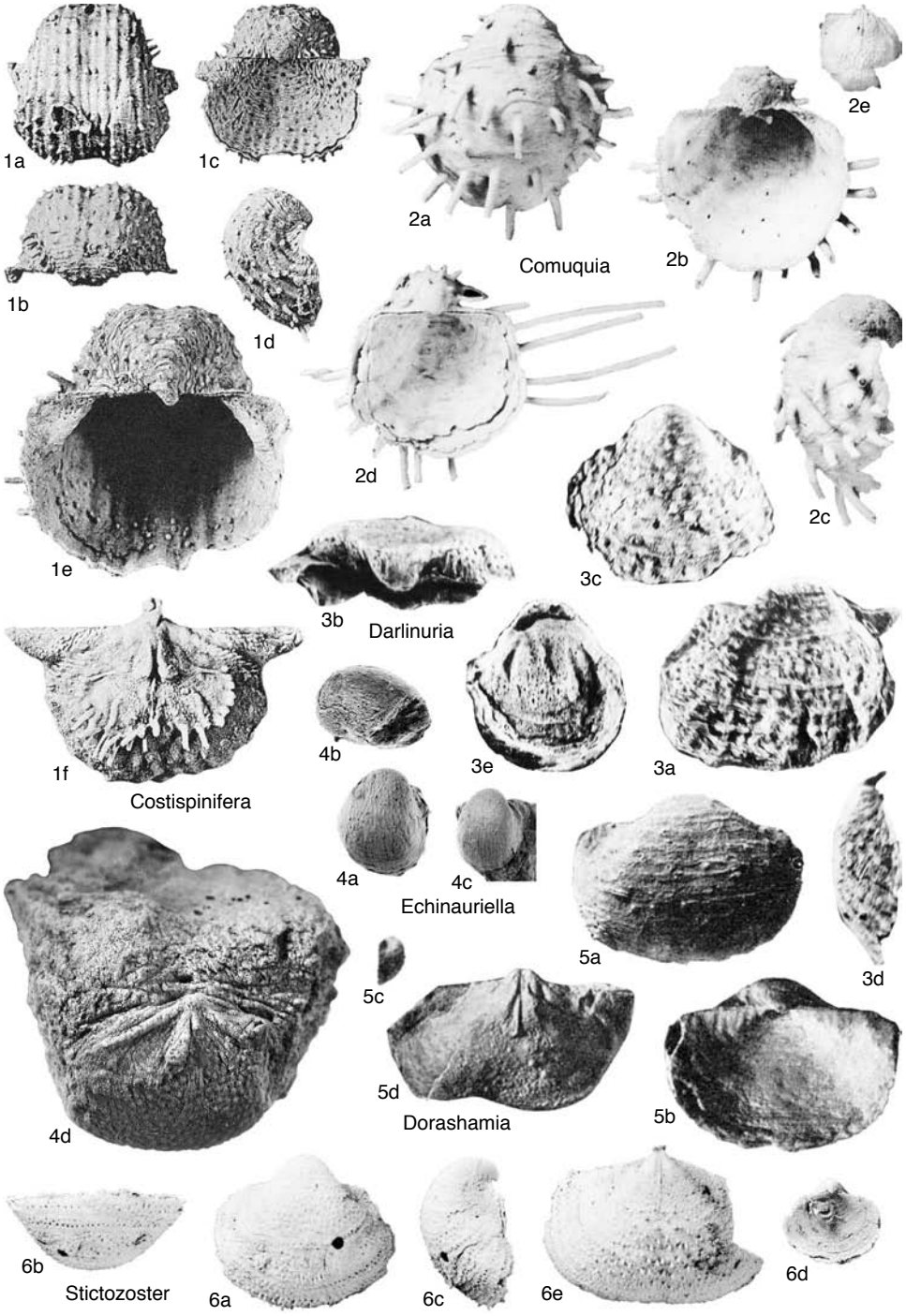

Fig. 285. Productellidae (p. 434–436).

78, ×1; *c,* ventral view of specimen, ×1; *d,* dorsal valve interior, ×3 (Sarytcheva & Sokolskaya, 1965).

Echinauris Muir-Wood & Cooper, 1960, p. 221 [**E. lateralis;* OD]. Small, subcircular outline, with small, well-differentiated ears; ventral corpus strongly inflated in transverse profile, cavity moderately deep; exterior smooth, but for erect spines covering both valves, clusters of thicker spines on flanks; ear baffles ventrally; dorsal lateral ridges separate ears, long endospines anterolaterally. *Lower Permian (Sakmarian)–lower Upper Permian (Wordian):* USA, Tibet.——Fig. 286,*2a–e.* **E. lateralis,* Upper Permian, Word Limestone, Texas; *a,* holotype, ventral view, USNM 124052a, ×1 (Muir-Wood & Cooper, 1960); *b,* dorsal view of specimen, ×1.5; *c,* lateral view of specimen, ×1.5; *d,* ventral view of shell with much of ventral valve missing, ×1 (Cooper & Grant, 1975); *e,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

?Lethamia Waterhouse, 1973, p. 38 [**L. ligurritus;* OD]. Poorly defined; medium size, concavoconvex with shallow corpus cavity; spines seemingly erect on both valves; ribbing absent, rugae weak. If with geniculate profile, would be better accommodated in the Levipustulini of the Plicatiferinae. *Lower Permian–lower Upper Permian (Kazanian):* New Zealand, ?Australia.

Neoplicatifera Ching, Liao, & Hou, 1974, p. 309 [**Plicatifera huangi* Ustritsky in Ustritsky, Hu, & Chan, 1960, p. 26; OD]. Small to medium transverse corpus with long trail; ventral profile with weakly convex disk, weakly geniculate; flanks steep, nearly parallel; dorsal disk gently concave geniculate; corpus cavity moderately deep; rugae on both disks; weakly ribbed or smooth; spines fine, posteriorly on rugae, scattered anteriorly, curved row between umbonal slope and ears; dorsal valve with fine short spines; cardinal process bilobate; median septum long; lateral ridges, marginal ridges lost anteriorly. [Assigned to the Semicostellini of the Plicatiferinae if with strong geniculation and ribbing on trail; Ustritsky decided (1960) that the species described by Huang (1932, p. 38–41) was not *Plicatifera minor* (Schellwien) and renamed it *P. huangi*.]. *upper Lower Permian–Upper Permian (Kazanian):* China, Salt Range.——Fig. 286,*4a–d.* **N. huangi* (Ustritsky), Permian, China (Guizhou Province); *a–c,* shell viewed posteriorly, anteriorly, laterally, ×1; *d,* dorsal valve interior, ×1 (Huang, 1932).

Paraplicatifera Zhao & Tan, 1984a, p. 26[30] [**P. regularis;* OD]. Resembles *Neoplicatifera,* but differs in its clearly defined anterior ribbing; dorsal valve unknown, but assumed spinose. *Lower Permian (Artinskian)–lower Upper Permian (Wordian):* China.——Fig. 286,*3a–c.* **P. regularis,* Permian, China; holotype, viewed posteriorly, anteriorly, laterally, HB 257, ×2 (Zhao & Tan, 1984a).

Pseudoavonia Wang in Zhang, Fu, & Ding, 1983, p. 312 [**Avonia lopingensiformis* Ustritsky in Ustritsky, Hu, & Chan, 1960, p. 28; OD]. Poorly known, resembles *Costispinifera,* but lacks concentric ornament on ventral umbo, perhaps fewer dorsal spines; apparently has stronger marginal ridges at sides of dorsal disk. *Lower Permian (Artinskian):* China.——Fig. 286,*6a,b.* **P. lopingensiformis* (Ustritsky), Chihsian, Xinjiang; ventral valve viewed anteriorly, posteriorly, ×1 (Zhang, Fu, & Ding, 1983).

Stictozoster Grant, 1976, p. 96 [**S. leptus;* OD]. Small, outline circular; evenly concavoconvex; ribs, rugae absent, but with weak lamellose ornament; spines fine, of equal dimensions, arranged on variable concentric bands on both valves; cardinal process small with variable pit; median septum thin, short; endospines extensive in both valves. *Lower Permian (Artinskian):* Thailand, western and eastern Timor, Indonesia, Western Australia, western Malaysia.——Fig. 285,*6a–e.* **S. leptus,* Permian, Ko Muk, Thailand; *a–c,* holotype, viewed ventrally, anteriorly, laterally, ×2; *d,* dorsally, USNM 212105, ×1; *e,* dorsal valve interior, ×2 (Grant, 1976).

Tubersulculus Waterhouse in Bamber & Waterhouse, 1971, p. 208 [**T. maximus;* OD]. Medium size, deeply concavoconvex profile; ventral sulcus and dorsal fold produce tubiform median trail; ribbing absent, concentric ornament of weak lamellae; spines with swollen bases, densely spaced on both valves, concentrically arranged anteriorly; cardinal process bilobed, quadrifid; adductor scars indistinct; lateral ridges separate ears; disk interior strongly endospinose. *upper Upper Carboniferous (Gzhelian)–Lower Permian (Artinskian):* Canada, Russia.——Fig. 286,*5a–e.* **T. maximus,* Lower Permian, Jungle Creek Formation, Yukon Territory; *a,b,* holotype, internal mold viewed ventrally, dorsally, GSC 26393, ×1; *c,* ventral valve exterior, ×1; *d,* replica of dorsal exterior, ×1; *e,* incomplete mold of ventral valve interior, ×1 (Bamber & Waterhouse, 1971).

Zhuaconcha Liang, 1990, p. 183[463] [**Z. hirsutispins;* OD]. Poorly preserved material. Small to medium size with weakly concavoconvex profile; hinge slightly less than maximum width; spines fine, closely covering both valves; ribbing, concentric ornament absent; dorsal marginal ridge, raised adductor scars; apart from marginal ridge genus similar to *Echinauriella.* Illustrations inadequate for publication. *Upper Permian (Kazanian):* China.

Tribe INSTITIFERINI Muir-Wood & Cooper, 1960

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 927, *ex* Institiferinae Muir-Wood & Cooper, 1960, p. 203]

Minute to small shells with relatively deep corpus cavity, bearing concentric ornament, coarse ribbing on trails strongly deflected as flanges or gutters; spines on ventral corpus only. *Lower Carboniferous (Viséan).*

Institifera Muir-Wood & Cooper, 1960, p. 203 [**Productus tessellatus* de Koninck, 1847b, p. 110;

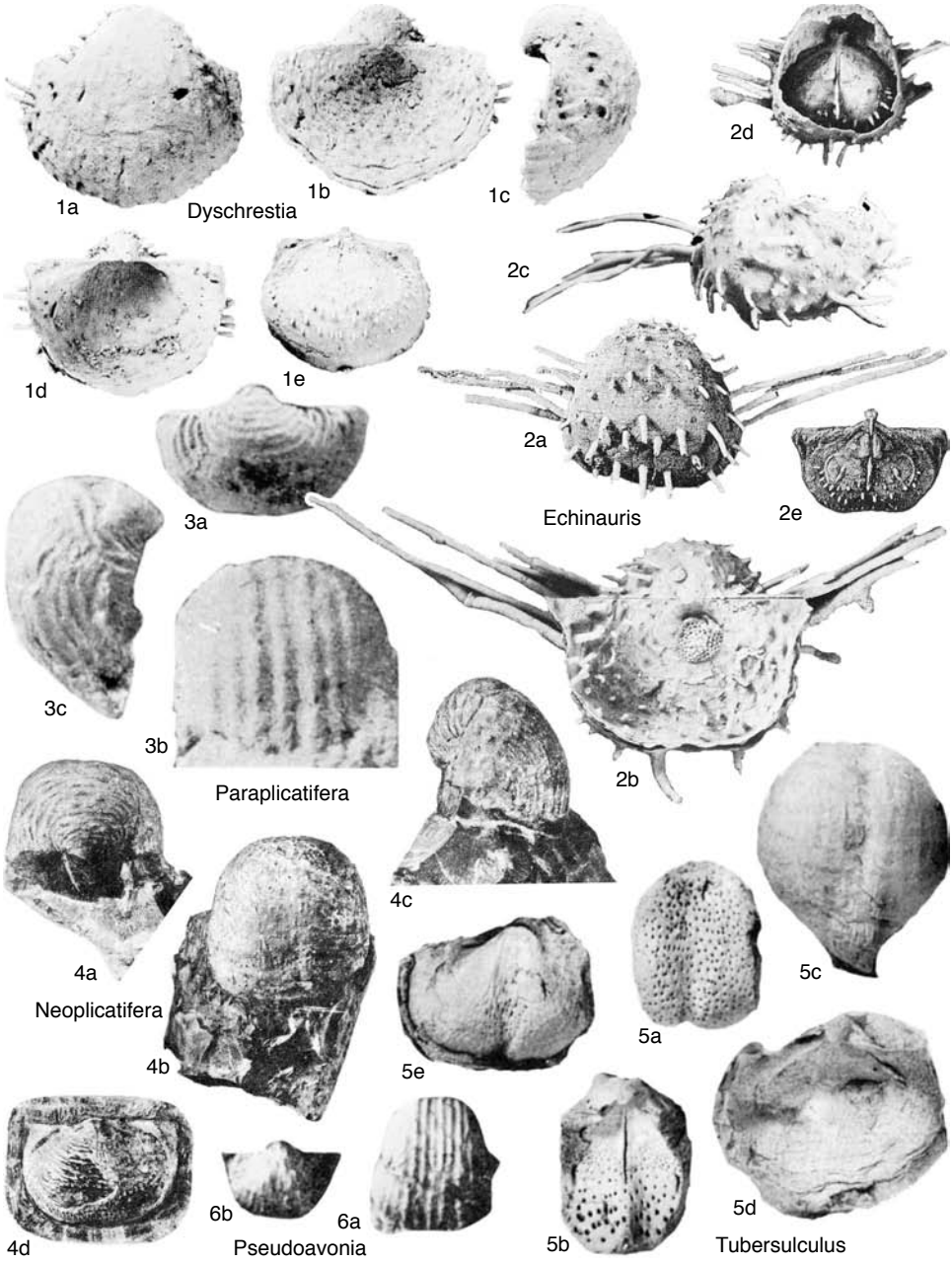

FIG. 286. Productellidae (p. 434–436).

OD]. Deep corpus, but slightly concave dorsal valve; ribbing variable, but clear anteriorly and especially on elaborate bordering structures that roll dorsally inward, ventrally outward; spines fine from concentric swollen bases. *Lower Carboniferous (Viséan):* western Europe.——FIG. 287,*2a–e. *I. tessellata* (DE KONINCK), Viséan, Ireland; *a,* shell viewed ventrally with section of recurved flange

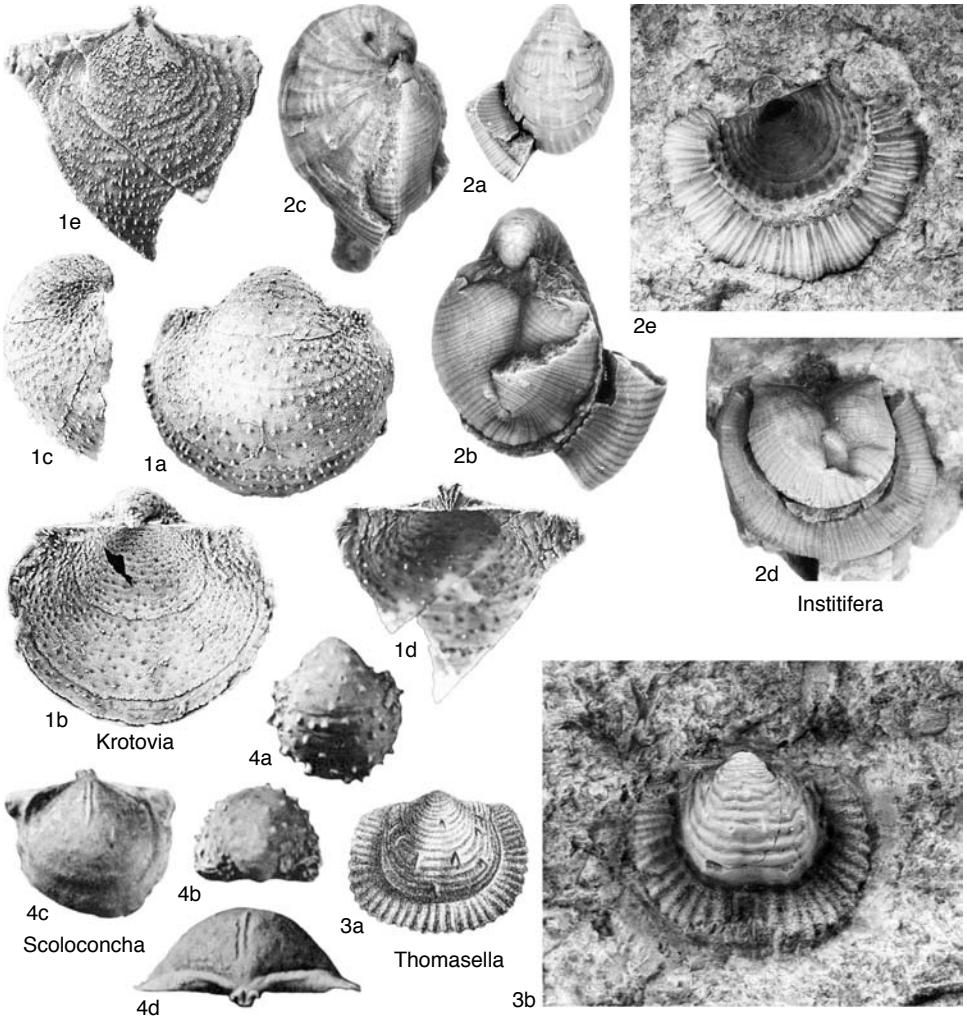

FIG. 287. Productellidae (p. 436–439).

preserved, Cork, ×2; *b,c,* shell viewed dorsally, laterally with its inwardly turned dorsal flange, anteriorly recurved ventral flange, Cork, ×3; *d,* dorsal view of shell with complete dorsal, ventral flanges, Cork, ×3; *e,* dorsal view of corpus (flange missing) plus ventral flange, Kildare, ×2 (new).

?Thomasella FREDERICKS, 1928, p. 778 [**Productus wrighti* DAVIDSON, 1861, p. 162; OD]. Very small, corpus around 5 mm width; rugose visceral disk, ribbed flange; spines few from ventral rugae. *Lower Carboniferous (Viséan):* British Isles.——FIG. 287,*3a,b.* **T. wrighti* (DAVIDSON), Viséan, Cork, Ireland; *a,* drawing of ventral exterior, with flange, ×3 (Davidson, 1861); *b,* lectotype, same specimen, BMNH B 40097, ×4 (new).

Tribe KROTOVIINI Brunton, Lazarev, & Grant, 1995

[Krotoviini BRUNTON, LAZAREV, & GRANT, 1995, p. 926]

Concentric ornament weak or lacking; ventral profile an ideal spiral; shallow corpus cavity. *Lower Carboniferous (Viséan)–Upper Carboniferous (Serpukhovian, ?Bashkirian).*

Krotovia FREDERICKS, 1928, p. 779 [**Productus spinulosus* J. SOWERBY, 1814 in 1812–1815, p. 155; OD]. Spine bases swollen (tuberculate), dense, quincuncially arranged; thin shelled; weakly developed marginal ridges; cardinal process quadrifid.

Lower Carboniferous (Viséan)–lower Upper Carboniferous (Serpukhovian, ?Bashkirian): Eurasia, northern Africa.——FIG. 287,*1a–e. *K. spinulosa* (J. SOWERBY), silicified specimens, Asbian, Fermanagh, British Isles; *a–c,* shell viewed ventrally, dorsally, laterally, ×2.3; *d,e,* incomplete dorsal valve viewed posterodorsally, internally, ×3.6 (Brunton, 1966).

Scoloconcha GORDON, 1966, p. 583 [**Productus indianensis* HALL, 1858b, p. 13; OD]. Small, around 6 mm wide; spines less dense than *Krotovia,* may be roughly concentric; cardinal process trifid, strong marginal structures. *Lower Carboniferous (middle Viséan):* USA.——FIG. 287,*4a–d. *S. indianensis* (HALL), middle Viséan, Indiana; *a,b,* ventral, posterior views of shell, ×3; *c,* internal view of dorsal valve, ×3; *d,* posterior view of dorsal valve interior, ×4 (Gordon, 1966).

Subfamily MARGINIFERINAE Stehli, 1954

[Marginiferinae STEHLI, 1954, p. 321, *partim*]

Ribbing normally dominates (may be reduced in Permian) concentric ornament; ventral profile commonly geniculate at start of trail growth; corpus cavity commonly shallow, becoming deep in Permian. *Lower Carboniferous (upper Tournaisian)–Upper Permian (Changhsingian).*

Tribe MARGINIFERINI Stehli, 1954

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 927, *ex* Marginiferinae STEHLI, 1954, p. 321, *partim*]

Ventral spines, rarely on both valves; always ribbed, but weak; commonly series of few dorsal trails, corpus cavity deep. *Lower Permian (Artinskian)–Upper Permian (Changhsingian).*

Marginifera WAAGEN, 1884, p. 713 [**M. typica;* OD] [=*Strigospina* LIAO, 1979, p. 535 (type, *S. lineata;* OD)]. Outline subquadrate with well-differentiated, wide ears; ventral profile strongly convex near geniculation, dorsal disk weakly concave with series of two to three trails; ribbing commonly weak, reticulate disks; spines in prominent rows along flanks plus others widely scattered on venter, none at hinge; ear baffles in both valves; dorsal lateral ridges strongly divergent, continue straight across ears, becoming marginal ridge; endospines in single row anterior to brachial ridges. *Lower Permian (upper Artinskian)–lower Upper Permian (Kazanian):* Himalayas, southeastern Asia, north, northeastern China.——FIG. 288,*1a–e. *M. typica,* Permian, Wargal Limestone, Pakistan, Khisor Range; *a,b,* posterior, anteroventral views of ventral valve, ×1.5; *c,* dorsal view of shell, ×2; *d,* lateral view of shell, ×2; *e,* dorsal valve interior, ×2 (Grant, 1968).

Entacanthadus GRANT, 1993b, p. 13 [**E. chioticus;* OD]. Small, moderately deep cavity resembling *Marginifera* in shape, but lacking ribbing and with small ears; dorsal valve weakly concave, geniculate, with series of closely spaced trails; spines in row at flanks, widely scattered over ventral corpus; dorsal adductor scars slightly arched medianly over start of short median septum. *upper Lower Permian (Kungurian):* Greece.——FIG. 288,*3a–e. *E. chioticus,* Kungurian, Khios Island; *a,* holotype, viewed ventrally, USNM 402157, ×2; *b,* dorsal view of shell, ×2; *c,d,* ventral valve viewed laterally, internally, ×2; *e,* dorsal valve interior, ×2 (Grant, 1993b).

?Jipuproductus SUN, 1983, p. 123 [**J. jipuensis;* OD]. Poorly known, seemingly similar to *Marginifera,* but condition of dorsal trails unknown, probably differing in its small ears, prominent rugae on flanks, dorsal cardinal ridges. *upper Lower Permian (Artinskian):* Xizang, Tibet.

Otariella WATERHOUSE, 1978, p. 30 [**Marginifera otaria* GRANT, 1976, p. 115; OD]. Resembles *Marginifera,* but differs with trail overhanging dorsal disk, in lacking ribs, although there are elongate spine bases on trail; widely extended concavoconvex ears with unusually deep auricular cavities, somewhat twisted appearance; dorsal valve seemingly with only one trail; spine row on flanks less prominent; dorsal interior with more numerous endospines. *Lower Permian (Artinskian–lower Kungurian):* Thailand.——FIG. 288,*2a–e. *O. otaria* (GRANT), Permian, Khao Chang; *a,b,* holotype viewed ventrally, laterally, USNM 212259, ×2; *c,* holotype viewed dorsally, USNM 212259, ×1; *d,* shell viewed anteroventrally, ×2; *e,* dorsal valve interior, ×2 (Grant, 1976).

Probolionia COOPER, 1957, p. 27 [**P. posteroreticulata;* OD]. Small with well-differentiated ears forming widest part of shell; ventral profile with weakly convex disk, geniculation, convex trail; median sulcus from median disk; dorsal disk gently concave, geniculate, with several dorsal trails; ribbing originates near beak, with rugae forming reticulation; spines symmetrical on ears, venter, and row along flanks, no dorsal spines; lateral, marginal ridges complete. *upper Lower Permian (Kungurian)–lower Upper Permian (Kazanian):* USA, Pamir.——FIG. 289,*2a–d. **P. posteroreticulata,* Permian, Coyote Butte Formation, Oregon; *a–c,* holotype, viewed posteriorly, anteriorly, laterally, USNM 125369, ×2; *d,* drawing of longitudinal section showing dorsal trails, ×2 (Muir-Wood & Cooper, 1960).

Spinomarginifera HUANG, 1932, p. 16 [**S. kueichowensis;* OD] [=*Rugosomarginifera* XU, 1987, p. 224 (type, *Marginifera jisuensis* CHAO, 1927b, p. 149; OD); *Haydenoides* CHAN in YANG DE-LI & others, 1977, p. 352 (type, *H. orientalis;* OD)]. Small to medium, with wide hinge; weakly concavoconvex with long ventral trail anterior to geniculation, dorsal trail short; ribbing absent, but elongate spine bases; rugae irregular, narrow; spines commonly densely spaced, fine, but in some widely spaced

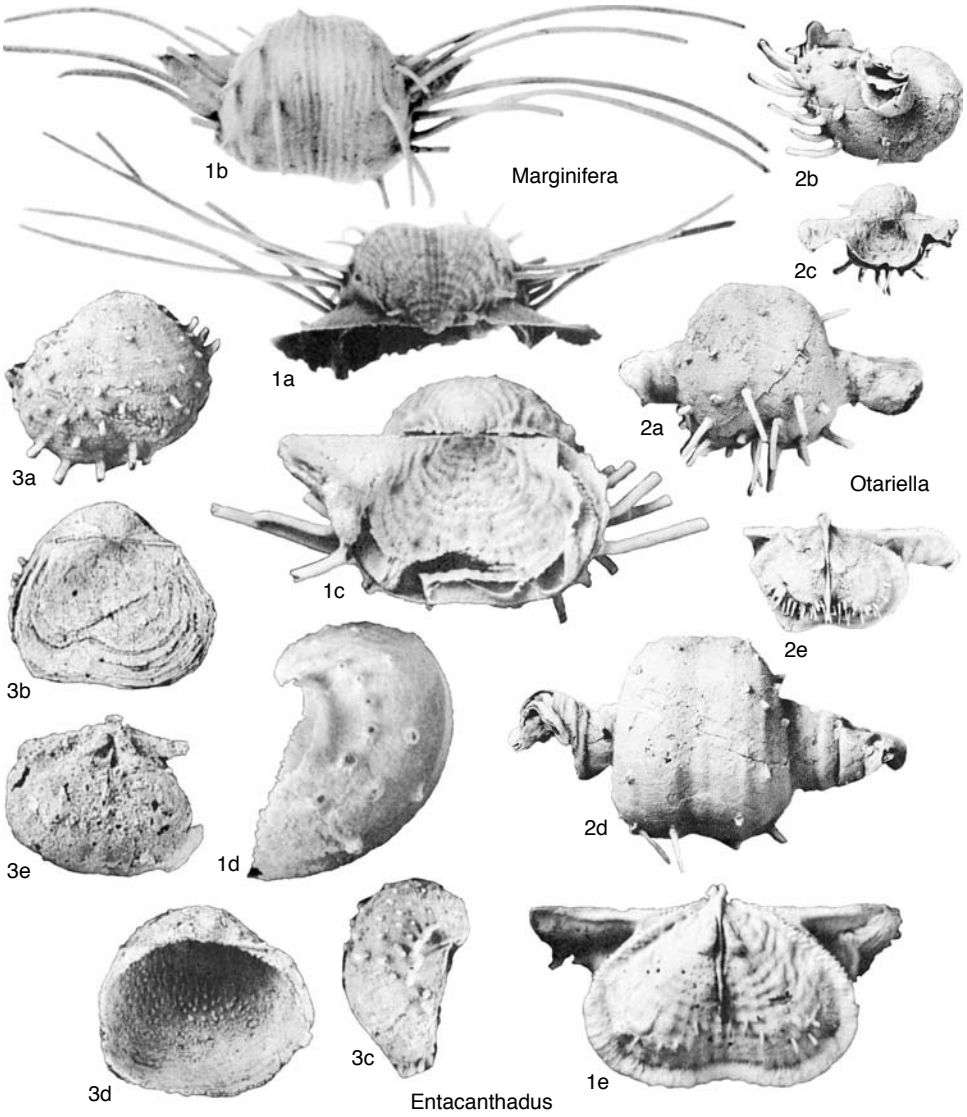

FIG. 288. Productellidae (p. 439).

anteriorly; dorsal valve with variably developed fine spines (the type species reported as lacking dorsal spines); marginal ridges strong in both valves, but ventrally incomplete anteriorly. *upper Lower Permian (upper Roadian)–Upper Permian (Changhsingian):* China, Japan, Afghanistan, Middle East.——FIG. 289,*1a–f.* **S. kueichowensis,* Permian Coal Series, Guizhou, China; *a–c,* ventral, posterior, lateral views, ×1; *d,* ventral view with remnants of long spines, ×1; *e,* exfoliated dorsal valve interior, ×1; *f,* internal mold of dorsal valve, ×1 (Huang, 1932).

Tribe BREILEENIINI Brunton, 1997

[Breileeniini BRUNTON in BRUNTON & LAZAREV, 1997, p. 389]

Spines on both valves, ribs commonly start anteriorly on corpus with elongate spine bases posteriorly. *Lower Carboniferous (upper Tournaisian)–Upper Carboniferous (upper Moscovian).*

Breileenia BRUNTON in BRUNTON & LAZAREV, 1997, p. 389 [**Productus davidsoni* JAROSZ, 1917, p. 88;

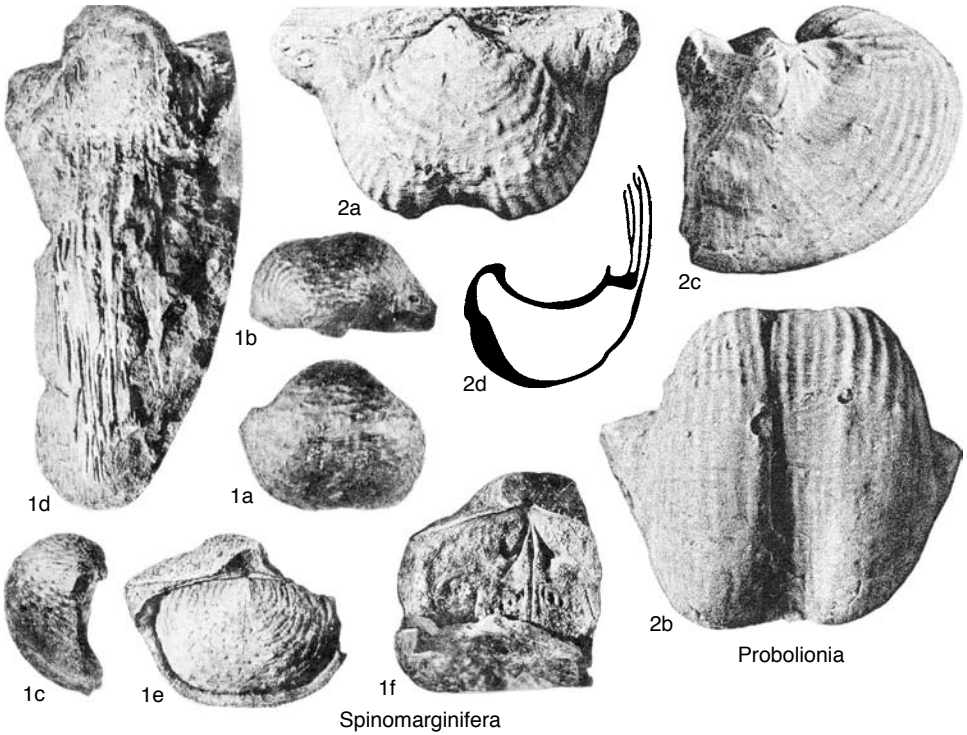

FIG. 289. Productellidae (p. 439–440).

OD]. Outline subrounded, corpus cavity moderately deep; spines distributed on both valves, ventrally with elongate bases or weak ribs originating at about half corpus length; growth lamellae weak, but may become prominent anteroventrally. *Lower Carboniferous (upper Tournaisian)–Upper Carboniferous (Serpukhovian):* western Europe, ?China, Canada.——FIG. 290,*1a–e. *B. davidsoni* (JAROSZ); *a,b,* lectotype, viewed ventrally, laterally, Asbian, Derbyshire, British Isles, BGS 72461, ×1; *c,* external mold of dorsal valve, Asbian, Derbyshire, ×1; *d,* lateral view of shell, Asbian, Derbyshire, ×1.5; *e,* ventral view of shell with broken ventral trail, Staffordshire, ×1.5 (Brunton & Lazarev, 1997).——FIG. 290,*1f,g. B. radiata* BRUNTON, Brigantian, Derbyshire; corpus viewed ventrally, dorsally, showing lateral ridges, ×2 (Brunton & Lazarev, 1997).

Desmoinesia HOARE, 1960, p. 226 [**Productus muricatus* NORWOOD & PRATTEN, 1855a, p. 14, *non* PHILLIPS, 1836; OD; =*Marginifera muricatina* DUNBAR & CONDRA, 1932, p. 222] [=*Rudinia* MUIR-WOOD & COOPER, 1960, p. 229, obj.]. Outline transverse, ventral umbo weakly inflated, irregularly rugose, weakly ribbed on corpus, trails; ventral spines on ribs, becoming concentric on anterior corpus and trail; dorsal spines sparse, reduced in later species; ventral ear baffles, subperipheral ridge. *Upper Carboniferous (upper Moscovian):* North America.——FIG. 290,*2a–f. *D. muricatina* (DUNBAR & CONDRA), Desmoinesian, Oklahoma; *a,* ventral view of shell, ×2; *b,c,* posterior, dorsal views of shell, ×2; *d,* lateral view of shell, ×1; *e,* ventral valve interior, ×2; *f,* dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Sandia SUTHERLAND & HARLOW, 1973, p. 41 [**S. brevis;* OD]. Radial ribbing relatively strong, posterior reticulation; dorsal spines thin plus few thick ones anteriorly. *Upper Carboniferous (middle Moscovian):* southern North America.——FIG. 290,*3a–f. *S. brevis,* middle Moscovian, New Mexico; *a,b,* holotype viewed ventrally, laterally, OU 7688, ×1; *c–e,* holotype viewed anteriorly, posteriorly, dorsally, ×2; *f,* dorsal valve interior, ×2 (Sutherland & Harlow, 1973).

Tribe INCISIINI Grant, 1976

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 927, *ex* Incisiidae GRANT, 1976, p. 103]

Outline commonly anteriorly bilobate; ventral spines only, ribbing absent; hinge narrow; lateral profile not geniculate. *Lower Permian (upper Artinskian)–Upper Permian (Changhsingian).*

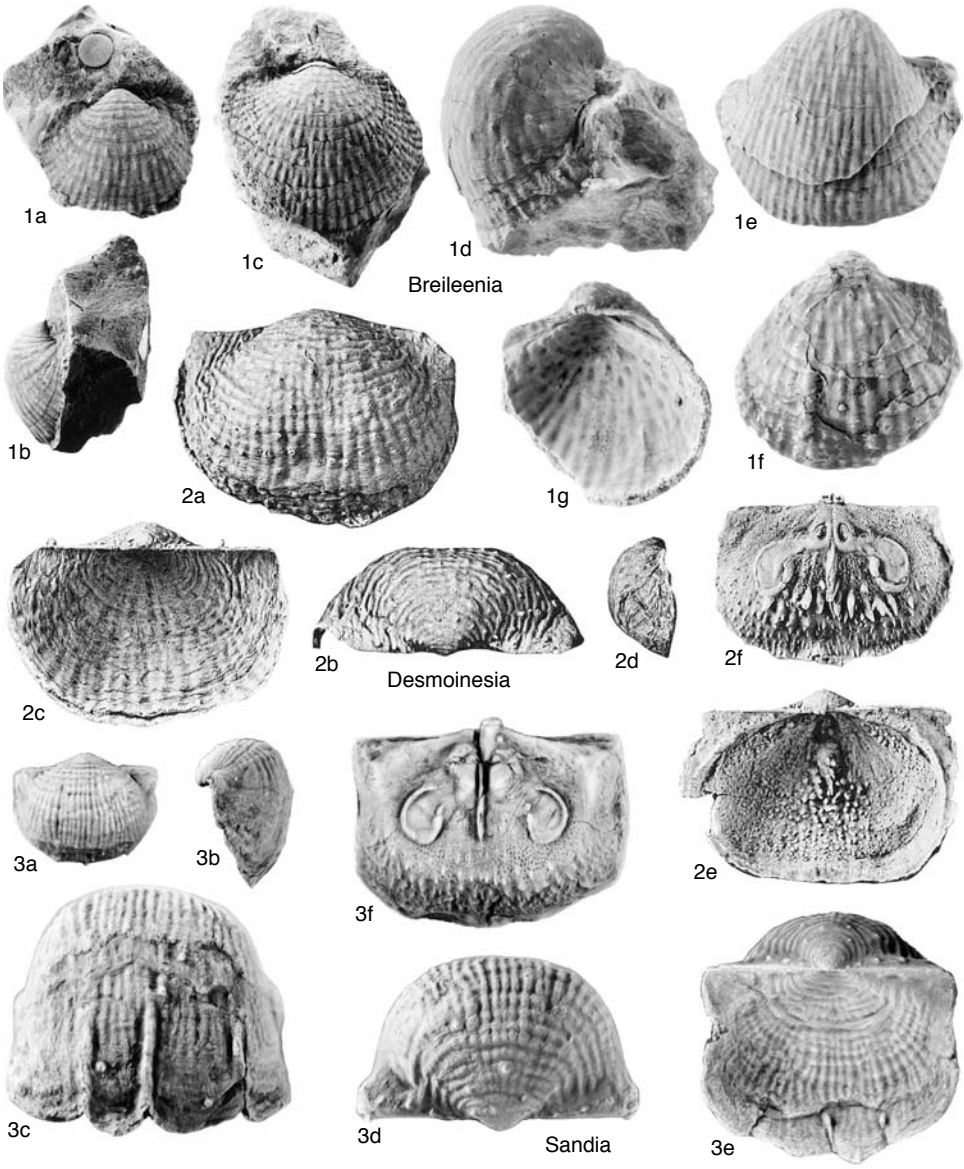

FIG. 290. Productellidae (p. 440–441).

Incisius GRANT, 1976, p. 103 [**I. concisus;* OD]. Outline narrow, widening anteriorly forming weakly bilobed anterior margin; profile nongeniculate, with strongly incurved ventral umbo; halteroid spines in row on each flank, scattered over venter, absent from sulcus and from dorsal valve; cardinal process small, bilobed; brachial ridges enclose elongate lobes occupying most of dorsal disk. *Lower Permian (upper Artinskian)–Upper Permian (Changhsingian):* Thailand, southern China, Greece.——FIG. 291,*3a–d. *I. concisus,* Permian, Ko Muk, Thailand; *a,* holotype viewed ventrally, USNM 212184, ×4; *b,* holotype viewed dorsally, USNM 212184, ×1.5; *c,* shell viewed laterally, ×3; *d,* dorsal valve interior, ×3 (Grant, 1976).

Cyrtalosia TERMIER & TERMIER, 1970, p. 455 [*C. circinata;* OD]. Poorly preserved and known, difficult to differentiate from *Incisius* other than by its reported lack of ventral spines. *Upper Permian (Tatarian):* Cambodia.——FIG. 291,*1a,b. *C.*

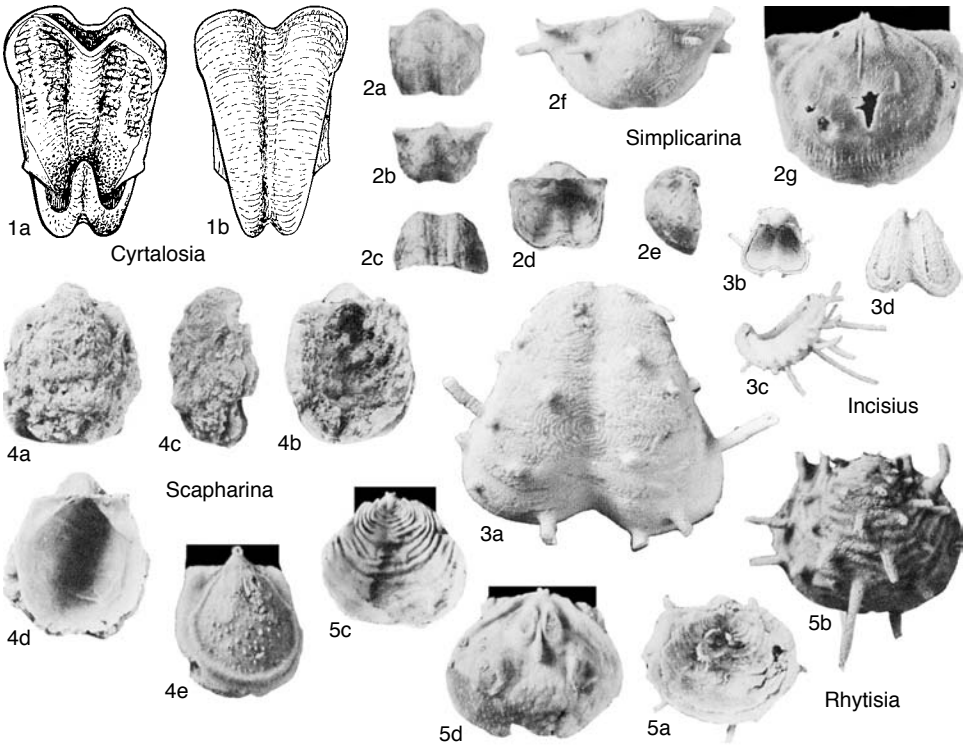

FIG. 291. Productellidae (p. 442–443).

circinata, Dzhulfian, Phnom Anseh; drawings of dorsal, ventral views, ×3 (Termier & Termier, 1970).

Rhytisia COOPER & GRANT, 1975, p. 967 [**R. rugosa;* OD]. Small, around 8 mm wide, rounded, concavo-convex profile, no anterior sulcus; rugae on both valves, no ribbing; spines relatively strong, scattered on ventral valve only; cardinal process sessile, bilobed; lateral ridges strongly divergent, separating ears, disappear anterolaterally; median septum short, tuberculate anteromedianly. *Lower Permian (Kungurian)–lower Upper Permian (Wordian):* USA.——FIG. 291,*5a–d. *R. rugosa,* Permian, Road Canyon Formation, Texas; *a,* holotype, viewed dorsally, USNM 152703c, ×2; *b,* ventral valve exterior, ×3; *c,* dorsal valve exterior, ×2; *d,* dorsal valve interior, ×3 (Cooper & Grant, 1975).

Scapharina COOPER & GRANT, 1975, p. 895 [**S. rugosa;* OD]. Small, elongate with rounded anterior margin; spines few, probably confined near posterior margin; shell commonly roughly lamellose; ear baffles in ventral valve; cardinal process small, supported by lateral ridges separating ears and continued as complete marginal ridge. *Upper Permian (Capitanian):* USA.——FIG. 291,*4a–e. *S. rugosa,* Permian, Bell Canyon Formation, Texas; *a–c,* holotype, viewed ventrally, dorsally, laterally, USNM 152657d, ×3; *d,* ventral valve interior, ×3; *e,* dorsal valve interior, ×3 (Cooper & Grant, 1975).

Simplicarina COOPER & GRANT, 1975, p. 966 [**S. incompta;* OD]. Small, outline subquadrate with small ears, rounded anterior margin; hinge approximately equal to maximum width; exteriors smooth with variable median sulcus; spines few, one or two on lateral slopes, venter; cardinal process small, sessile, bilobate; median septum short; lateral ridges at high angle from hinge, extend as marginal ridge, weak anteriorly, but with endospines. *upper Lower Permian (Roadian):* USA.——FIG. 291,*2a–g. *S. incompta,* Permian, Road Canyon Formation, Texas; *a–e,* holotype viewed ventrally, posteriorly, anteriorly, dorsally, laterally, USNM 153927a, ×1; *f,* ventral valve viewed posteriorly, ×2; *g,* dorsal valve interior, ×2 (Cooper & Grant, 1975).

Tribe PAUCISPINIFERINI Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 927, *ex* Paucispiniferinae MUIR-WOOD & COOPER, 1960, p. 319, *partim*] [=Hystriculininae LAZAREV, 1986c, p. 23; Caucasoproductinae G. KOTLYAR, 1989, p. 121, *partim;* Jiguliconchinae LAZAREV, 1986c, p. 22]

Commonly widest at hinge, with ventral median sulcus; always ribbed, ventral spines

only; corpus cavity may be deep. *Upper Carboniferous (Kasimovian)–Upper Permian (Tatarian).*

Paucispinifera Muir-Wood & Cooper, 1960, p. 319 [**P. auriculata;* OD]. Medium size, transverse outline with large ears forming widest part of shell; ribbing most strongly developed in geniculation region, lost at trail margin; rugae absent; about six spines symmetrically placed on ears, flanks, venter, smaller spines in rows separating ears from corpus; cardinal process sessile, broad with zygidium; lateral ridges strong, continued as complete marginal ridge. *upper Lower Permian (Roadian)–lower Upper Permian (Wordian):* southern USA.——Fig. 292,*1a–e. *P. auriculata,* Permian, Word Formation, Texas; *a,b,* holotype viewed anteriorly, posteroventrally, USNM 124054g, ×1; *c,* dorsal valve interior, ×1.5 (Muir-Wood & Cooper, 1960); *d,e,* shell viewed dorsally, laterally, ×1 (Cooper & Grant, 1975).

Anemonaria Cooper & Grant, 1969, p. 8 [**A. inflata;* OD; =*Marginifera sublaevis* King, 1931, p. 89, *partim*]. Subrectangular, ears extended; deeply concavoconvex; sulcus distinct; nearly smooth except for indistinct ribs on trail; spines few, in row on each flank, scattered over venter, visceral disk; ventral interior with small ear baffles; sessile cardinal process with zygidium. *Lower Permian (Sakmarian–Roadian):* USA, north and northeastern China.——Fig. 292,*2a–d. *A. inflata,* Permian, Cathedral Mountain Formation, Texas; *a,* ventral valve exterior, ×1; *b,* dorsal view of complete specimen, ×1; *c,d,* dorsal valve viewed internally, ×2, posteriorly, ×4 (Cooper & Grant, 1975).

Azygidium Waterhouse, 1983c, p. 153 [**Horridonia mitis* Hill, 1950, p. 17; OD]. Similar to *Anemonaria,* but with longer trail, no zygidium, but similarly weak or no ribbing. *Lower Permian:* eastern Australia (Dresden Formation).

Caricula Grant, 1976, p. 128 [**C. salebrosa;* OD]. Small, transverse, ears extended, geniculate; visceral disks strongly rugose, weakly ribbed, ribbing almost lost on trails; sulcus prominent; spines few, up to four across ears, six on venter; cardinal process internally V-shaped, on short shaft; median septum raised anteriorly; lateral ridges extend as low marginal ridges around corpus; brachial ridges prominent. *Lower Permian (Artinskian):* Thailand.——Fig. 293,*1a–e. *C. salebrosa,* Artinskian, Ko Muk; *a–c,* holotype viewed ventrally, dorsally, laterally, USNM 212368, ×3; *d,e,* ventral valve interior, dorsal valve interior, ×3 (Grant, 1976).

Caucasoproductus G. Kotlyar, 1989, p. 121 [**P. (Productus) dichotomocostatus* Licharew, 1937, p 39; OD]. Small, asymmetric, trails may flare; plano- to weakly concavoconvex corpus; ribbing thin with dichotomous branching; visceral disks reticulate; spine row near hinge, widely scattered over valve; marginal ridge around dorsal cavity. *Upper Permian (Tatarian):* North Caucasus.——Fig. 292,*4a–d. *C. dichotomocostatus* (Licharew), Dzhulfian, Urushten; *a–c,* ventral, dorsal, lateral views of incomplete specimen, ×1; *d,* posteroventral view of incomplete specimen, ×1 (Licharew, 1937).

Costiferina Muir-Wood & Cooper, 1960, p. 277 [**Productus indicus* Waagen, 1884, p. 687; OD]. Larger medium size, transverse in ventral outline, with well-defined ears; ventral profile strongly, but evenly convex; dorsal disk almost flat, geniculate with trail; ribbing originates near umbo, widening to coarsely irregular on trail; disks reticulate; spines large, on ears, in row separating ears and on trail; dorsal lateral ridges bend sharply to separate ears, continue as marginal ridge; adductor scars large with anterior and posterior components; long median septum; valves thick shelled. *upper Lower Permian (Artinskian)–Upper Permian (Kazanian):* Pakistan, Western Australia, southeastern Asia, China.——Fig. 292,*3a–c. *C. indica* (Waagen), Upper Permian, upper *Productus* Limestone, Salt Range, Pakistan; ventral valve viewed posteroventrally, anteriorly, laterally, ×1 (Muir-Wood & Cooper, 1960).——Fig. 292,*3d–f. C. vishnu* (Waagen), Permian, upper *Productus* Limestone, Salt Range, Pakistan; *d,* ventral valve interior, ×1; *e,f,* dorsal valve interior, lateral view, ×1 (Muir-Wood & Cooper, 1960).

Elliottella Stehli, 1955, p. 711, *nom. nov. pro Psilonotus* Stehli, 1954, p. 323, *non* Walker, 1834 [**Psilonotus transversalis* Stehli, 1954, p. 324; OD]. Small, somewhat transverse shells, corpus cavity commonly moderately deep; ventral median sulcus; ventral disk convex, profile geniculate; ribbing strong, originating posteriorly on disks; spines widely scattered, arising from ribs; weak divergent lateral ridges extend across ears; median septum reaches margin of disk. *Lower Permian (Artinskian):* southern USA.——Fig. 293,*2a,b. *E. transversalis* (Stehli), Lower Permian, Bone Spring Formation, Texas; ventral valve viewed ventrally, laterally, ×1 (Stehli, 1954).——Fig. 293,*2c,d. E. minima* (Stehli), Lower Permian, Bone Spring Formation, Texas; shell viewed dorsally, dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Hystriculina Muir-Wood & Cooper, 1960, p. 210 [**H. texana;* OD]. Ventral spines sparse, include row on each umbonal flank; concentric ornament posteriorly, weak; lateral ridges strongly divergent, continued as ear baffles. *Upper Carboniferous (upper Kasimovian)–Permian:* North America, central Europe.——Fig. 293,*3a–f. *H. texana,* upper Kasimovian–Gzhelian, Texas; *a–d,* holotype viewed ventrally, posteriorly, dorsally, laterally, USNM 124034a, ×2; *e,f,* dorsal valve interior, posterior, ×3 (Muir-Wood & Cooper, 1960).

Jiguliconcha Lazarev, 1990, p. 81 [**Hystriculina gracilicosta* Lazarev, 1984, p. 71; OD]. Similar to *Hystriculina,* but lateral ridges weak, close to hinge. *Upper Carboniferous (Kasimovian):* eastern Europe.——Fig. 293,*5a–d. *J. gracilicosta* (Lazarev), Kasimovian, Moscow basin; *a,* anteroventral view of ventral valve, ×1; *b,c,* ventral, lateral views of ventral valve, ×1; *d,* dorsal valve interior, median septum broken, ×3 (new).

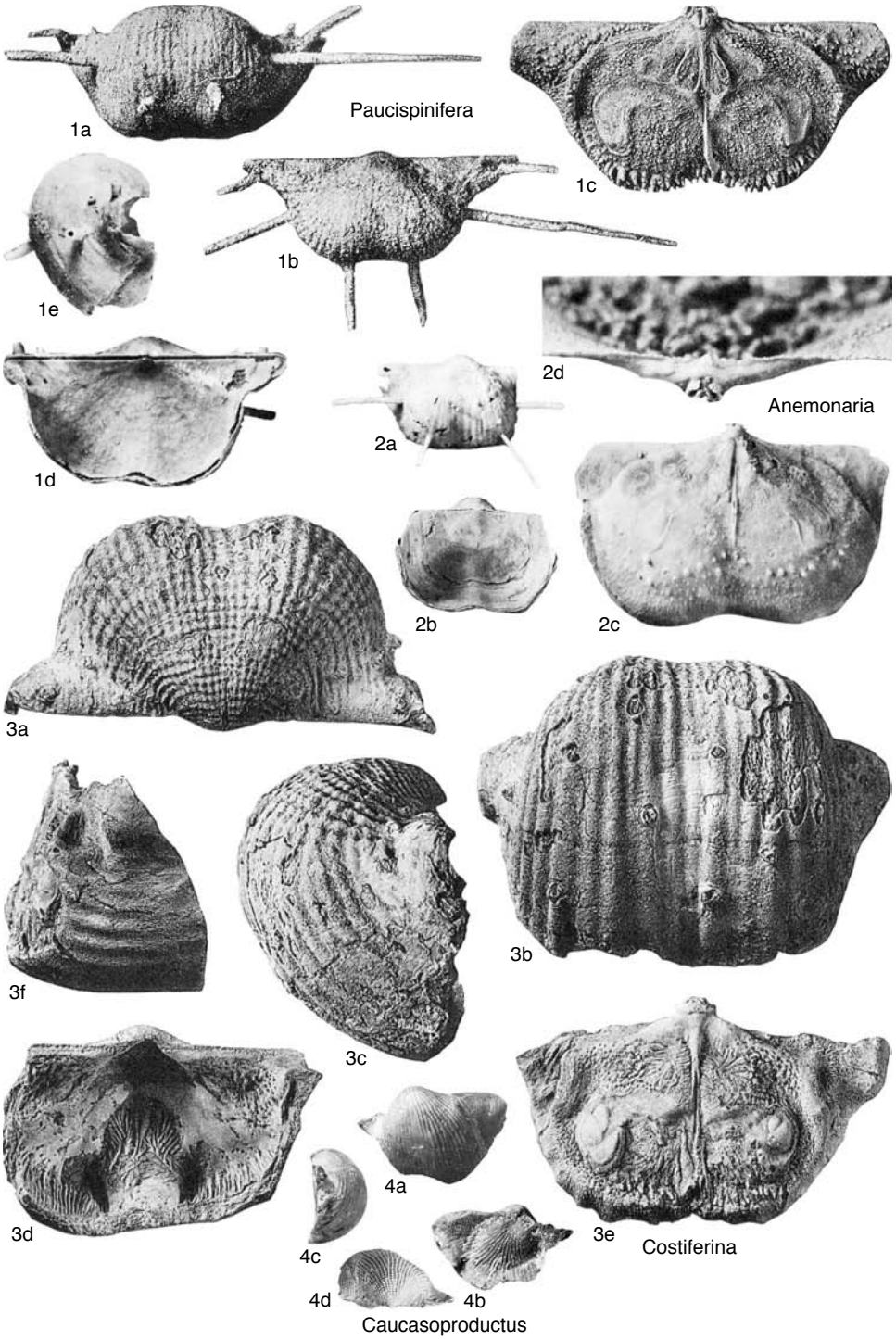

FIG. 292. Productellidae (p. 444).

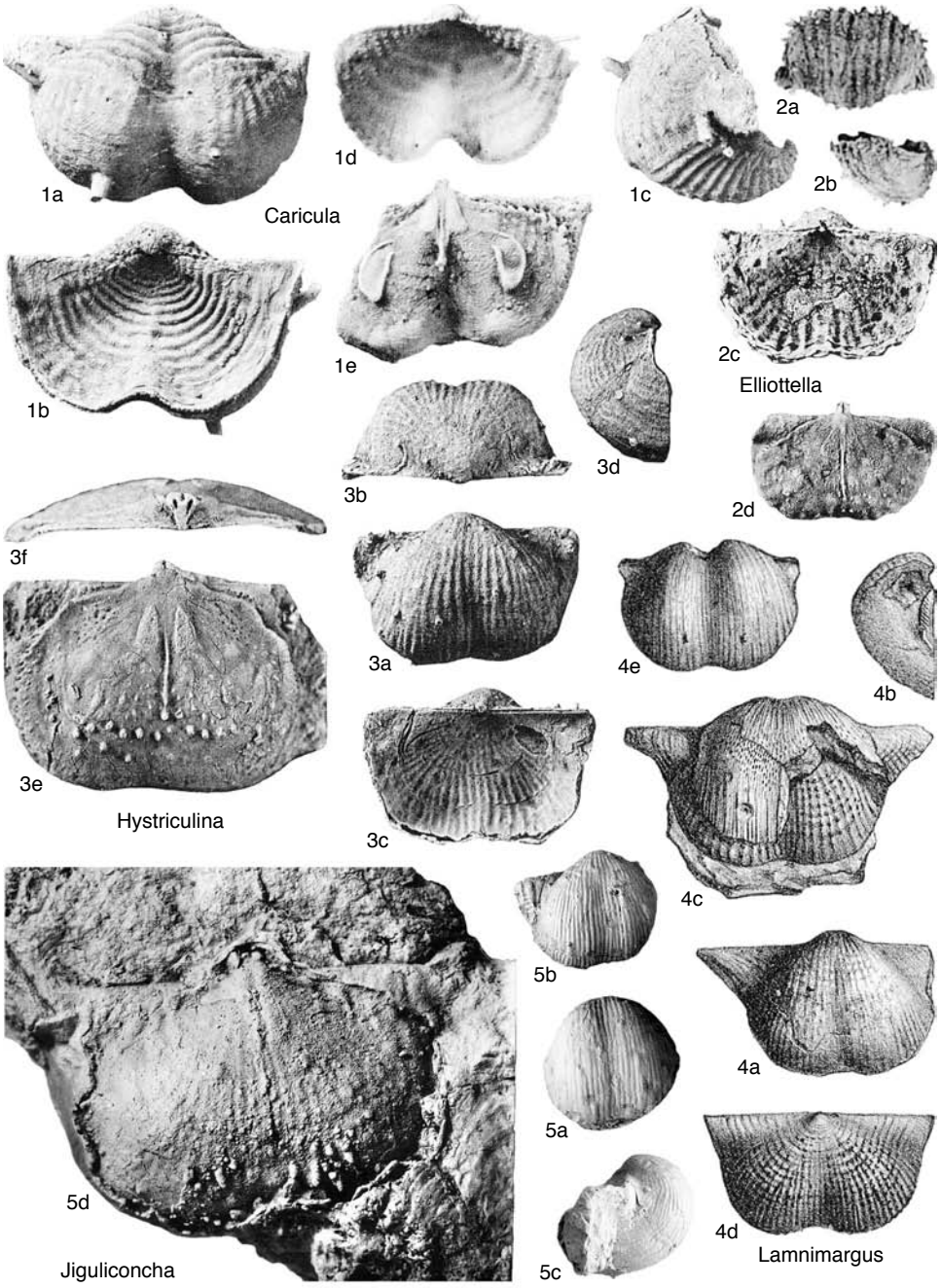

FIG. 293. Productellidae (p. 444–447).

Lamnimargus WATERHOUSE, 1975, p. 10 [**Marginifera himalayensis* DIENER, 1899, p. 39; OD]. Transverse with large ears forming wide hinge line; median sulcus originates near beak; disk reticulate; spines in row near hinge, in row on flanks, plus about two on venter; ventral interior with striated adductor scars; dorsal lateral ridges become complete marginal ridge. *upper Lower Permian (Kungurian):* Himalayas,

Nepal, Pamirs.——Fig. 293,*4a–e.* **L. himalayensis* (Diener), upper Lower Permian; *a,b,* lectotype (selected by Waterhouse, 1975) viewed ventrally, laterally, Kashmir, ×1; *c,* ventral view of shell with exfoliated, partially missing ventral valve, Spiti, ×1; *d,e,* external mold of dorsal valve, anteroventral view of shell, Spiti, ×1 (Diener, 1899).

Lampangella Waterhouse, 1983a, p. 121 [**L. lata;* OD]. Transverse outline with large ears; short ginglymus; ribbing prominent anteriorly; spines in row near hinge, row at ears, sparse on ventral corpus; low ear baffles. *Upper Permian (Tatarian):* Thailand.——Fig. 294,*1a–c.* **L. lata,* Upper Permian, Huali Tak Formation, northwestern Thailand; *a,* holotype, incomplete ventral valve exterior, TBR 441, ×2; *b,* ventral valve exterior, ×3; *c,* dorsal valve external mold, ×2.5 (Waterhouse, 1983a).

Liosotella Cooper, 1953, p. 36 [**L. rugosa;* OD]. Small to medium size with broad, shallow median sulcus; gently concavoconvex corpus, geniculate, long trails; steep flanks; ribbing strong only on trail; spines in curved rows at base of flanks, scattered variably on rest of valve; zygidium commonly present; dispositions of lateral ridges, extensions across ears variable; one or two rows of strong endospines anterior to well-marked brachial ridges, surfaces tuberculate. *upper Lower Permian (Roadian)–lower Upper Permian (lower Kazanian):* central, North America, northern and northeastern China.——Fig. 294,*2a–d.* **L. rugosa,* Upper Permian, Monos Formation, Sonora, Mexico; holotype viewed posteriorly, anteriorly, dorsally, laterally, USNM 115458, ×1 (Muir-Wood & Cooper, 1960).——Fig. 294,*2e–f.* *L. irregularis* Cooper & Grant, Upper Permian, Word Formation, Texas; dorsal valve exterior, interior, ×1 (Cooper & Grant, 1975).

Nudauris Stehli, 1954, p. 317 [**N. diabloensis;* OD]. Medium size, weakly concavoconvex profile; ears well developed at widest part of shell; weak ventral sulcus, dorsal fold; ribbing weak to obscure; rugae on both disks; spines in row near hinge, scattered on ventral valve; lateral ridges short, close to hinge; cardinal process trifid, median septum long, thin. *Lower Permian (Asselian–Kungurian):* USA.——Fig. 294,*4a–e.* **N. diabloensis,* Permian, Bone Spring Formation, Texas; *a–c,* ventral valve viewed ventrally, anteriorly, laterally, ×1; *d,* dorsal valve exterior, ×1; *e,* dorsal valve interior, ×1 (Cooper & Grant, 1975).

Oncosarina Cooper & Grant, 1969, p. 9 [**O. spinocostata;* OD]. Small, strongly concavoconvex profile with steep flanks; ventral sulcus weak or absent; disk smooth, ribbing originating anteriorly on disks, prominent on trail; spines thick in clusters on anterior ears, thinner on umbonal regions, lateral slopes, crests of costae; dorsal adductor scars on platforms overhanging medianly; cardinal process broad, variably bilobed, quadrifid; lateral ridges extend to separate ears. *Lower Permian (Artinskian–lower Kungurian):* USA.——Fig. 294,*3a–d.* **O. spinocostata,* Permian, Skinner Ranch Formation, Texas; *a,* holotype viewed ventrally, USNM 149824, ×2; *b,* holotype viewed laterally, USNM 149824, ×1; *c,* shell viewed dorsally, ×2; *d,* dorsal valve interior, ×3 (Cooper & Grant, 1975).

Retimarginifera Waterhouse, 1970, p. 123 [**R. perforata;* OD]. Small, transverse, widest at hinge; profile deeply concavoconvex, deep ventral sulcus; visceral disk reticulate with clear ribbing commonly extending along trail; six major spines, in pairs on ears, venter; sessile, trifid cardinal process; lateral ridges extend as marginal ridge that may be lost anteriorly. *Lower Permian (Artinskian–Kungurian):* Western Australia, Thailand, Himalayas, northern China.——Fig. 295,*1a–d.* **R. perforata,* Permian, Byro Group, Western Australia, Carnavon Basin; *a,* holotype viewed ventrally, U.W.A. 59282, ×2; *b,* ventral valve exterior, ×2 (Waterhouse, 1970); *c,* dorsal view of shell, ×1.5; *d,* dorsal valve interior, ×1.5 (Archbold, 1984).——Fig. 295,*1e–g.* *R. celeteria* Grant, Permian, Ko Muk, Thailand; *e,* dorsal view of shell, ×1; *f,g,* shell viewed ventrally, laterally, ×1 (Grant, 1976).

Shanxiproductus Duan & Li, 1985, p. 232 [**S. shanxiensis;* OD]. Resembling *Hystriculina,* but medianly sulcate, rugose on visceral disks, may form distal spine ridges on ventral trail; ventral internal marginal ridges. *Upper Carboniferous (Gzhelian)–Lower Permian (Asselian):* China.——Fig. 295,*2a–c.* **S. shanxiensis,* Asselian, Shanxi; anterior, posterior, lateral views of ventral valve, ×2 (Duan & Li, 1985).

Spinarella Cooper & Grant, 1975, p. 1058 [**S. perfecta;* OD]. Medium, outline rectangular, but with extended ears; deeply concavoconvex; ribbing low, variable over anterior disks, trails; rugae in posterior region producing varied degree of reticulation; spines in row across ears, scattered widely over ventral valve; ventral adductor scars sunken; cardinal process small, sessile, trifid to quadrifid; median ridge long; brachial ridges strong; inner surface strongly endospinose. *upper Lower Permian (Roadian):* USA.——Fig. 295,*3a–f.* **S. perfecta,* Permian, Road Canyon Formation, Texas; *a–c,* holotype, viewed ventrally, dorsally, laterally, USNM 148844a, ×1; *d,* ventral valve interior, ×1; *e,* ventral valve viewed posteriorly, ×1; *f,* dorsal valve interior, ×1 (Cooper & Grant, 1975).

Transennatia Waterhouse, 1975, p. 10 [**Productus gratiosus* Waagen, 1884, p. 691; OD] [=*Gratiosina* Grant, 1976, p. 131, obj.; *Asioproductus* Chan (Zhan) in Hou, Zhan, & Chen, 1979, p. 85 (type, *A. bellus;* OD); *Kurtomarginifera* Xu, 1987, p. 225 (type, *K. spinata;* OD)]. Small, outline subquadrate with small ears; ribs strongly defined, commonly converging into sulcus; rugae strong, producing reticulation on both disks; spines in row separating ears, scattered on disk, trail; cardinal process sessile quadrifid. *Lower Permian (?Kungurian), Upper Permian (Kazanian):* Himalayas, Thailand, China, Timor, Western Australia, Greece, Sicily.——Fig. 295,*4a–e.* **T. gratiosa* (Waagen), Upper Permian, Wargal Formation, Salt Range, Pakistan; *a,b,* ventral, dorsal views, ×1; *c–e,* lateral, ventral interior, dorsal interior, ×2 (Grant, 1976).——Fig.

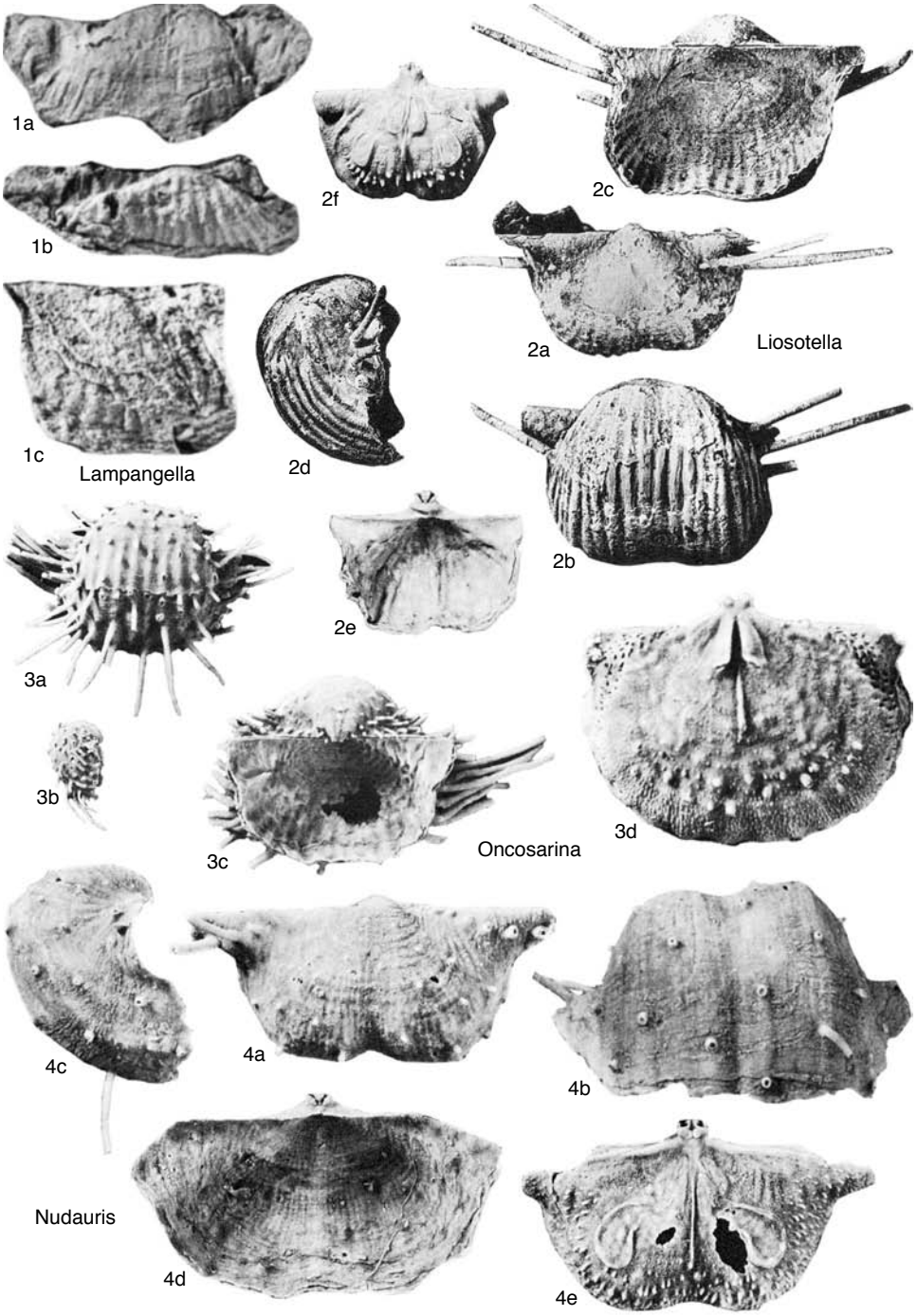

FIG. 294. Productellidae (p. 447).

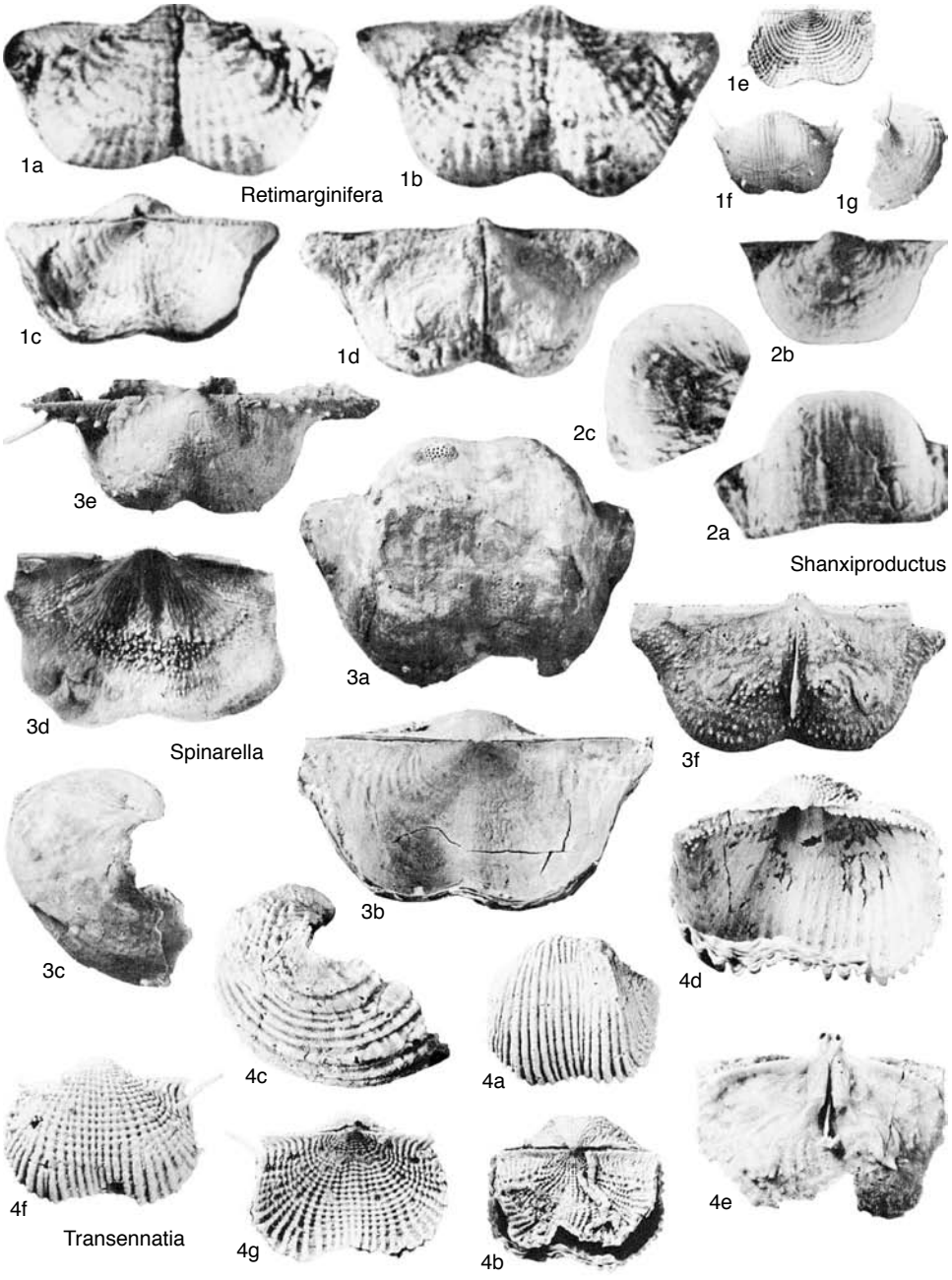

FIG. 295. Productellidae (p. 447–449).

295,*4f,g. T. insculpta* (GRANT) Permian, Ko Muk, Thailand; ventral, dorsal views of shell, ×2 (Grant, 1976).

Xestosia COOPER & GRANT, 1975, p. 1063 [**X. obsolescens;* OD]. Resembling *Spinarella,* but with clumps of spines on ears, internally with endospines

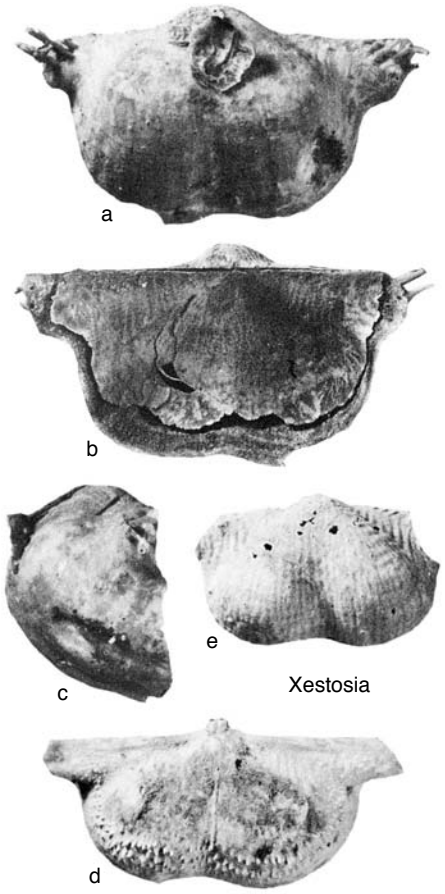

FIG. 296. Productellidae (p. 449–450).

distributed only marginally. *upper Lower Permian (Kungurian):* USA.——FIG. 296*a–c. *X. obsolescens,* Permian, Cathederal Mountain Formation, Texas; holotype, viewed ventrally, dorsally, laterally, USNM 148861b, ×1 (Cooper & Grant, 1975). ——FIG. 296*d,e. X. schucherti* (KING); dorsal valve interior, ventral valve exterior, ×1 (Cooper & Grant, 1975).

Subfamily PLICATIFERINAE Muir-Wood & Cooper, 1960

[Plicatiferinae MUIR-WOOD & COOPER, 1960, p. 201]

Shell geniculated, with ventral disk only gently convex; corpus cavity moderately shallow to rarely deep anteriorly; ribbing lacking, weak or only anteriorly on trails; concentric ornament normally strong, especially rugae; spines sparsely or densely distributed on ventral valves, commonly including near hinge, rarely on both. *Upper Devonian (upper Famennian)–Upper Permian (Kazanian).*

Tribe PLICATIFERINI Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 927, *ex* Plicatiferinae MUIR-WOOD & COOPER, 1960, p. 201]

Corpus cavity moderately deep, trail long; ribbing absent or weak, only on trails; rugae or lamellae strongly developed on corpus; ear baffles in dorsal valve, rarely also in ventral valve. *Carboniferous (middle Viséan–Bashkirian), ?Upper Carboniferous.*

Plicatifera CHAO, 1927b, p. 25 [**Productus plicatilis* J. DE C. SOWERBY, 1824 in 1823–1825, p. 85; OD]. Transverse outline; rugae strongly developed on corpus, ribbing absent or incipient, narrow, may extend over trail; stout spines near hinge, on flanks, few anteriorly, smaller ones scattered on rugae. *Lower Carboniferous (middle Viséan–upper Viséan):* Eurasia, northern Africa.——FIG. 297,*1a–c. *P. plicatilis* (J. DE C. SOWERBY), Viséan, Derbyshire, British Isles; lectotype, viewed anteroventrally, dorsally, posteriorly, BMNH B 60960, ×2 (new).——FIG. 297,*1d–f. P. pseudoplicatilis* (MUIR-WOOD, 1928), Asbian, Fermanagh, silicified specimens; *d,* dorsal valve interior, ×1.5; *e,* interiors of two incomplete articulated valves viewed anteriorly, ×1.5; *f,* incomplete juvenile ventral valve exterior showing pedicle sheath, *arrow,* clasping spines, ×10 (Brunton & Mundy, 1993).

Absenticosta LAZAREV, 1991, p. 58 [**A. uldzejtuensis* SUUR'SUREN & LAZAREV in LAZAREV, 1991, p. 58; OD]. Rugae thin, undulose, irregular; spines thin, densely arranged ventrally, dorsal spines few, thicker anteriorly; lateral ridges continue weakly to anterior margin. *Lower Carboniferous (?middle Viséan, upper Viséan):* Transbaikalia, Mongolia.——FIG. 297,*4a–d. *A. uldzejtuensis* (SUUR'SUREN & LAZAREV), middle Viséan–upper Viséan, Mongolia; *a,b,* incomplete shell viewed anteroventrally, posteriorly, ×1.5 (new); *c,* external mold of dorsal valve, ×1; *d,* anterolateral view of external mold of dorsal valve, ×1 (Lazarev, 1991).

Aseptella MARTÍNEZ CHACÓN & WINKLER PRINS, 1977, p. 18 [**A. asturica;* OD]. Small, up to 14 mm wide, transverse shell; rugae narrow but clear or lamellose, no ribs; ventral spines stout, in two radiating rows on each flank; dorsal interior with strong lateral ridges and ear baffles. *Carboniferous (lower Serpukhovian–Bashkirian), ?Upper Carboniferous:* Spain, Argentina, Thailand.——FIG. 297,*2a–d. *A. asturica,* lower Bashkirian, Oviedo; *a,* external mold of ventral valve, ×8.5; *b,* internal mold of ventral valve, ×4; *c,* external mold of dorsal valve, ×4; *d,* internal mold of dorsal valve, ×7 (Martínez Chacón & Winkler Prins, 1977).

Crossacanthia GORDON, 1966, p. 580 [**C. perlamellosa;* OD]. Small; rounded shells, no ribbing, con-

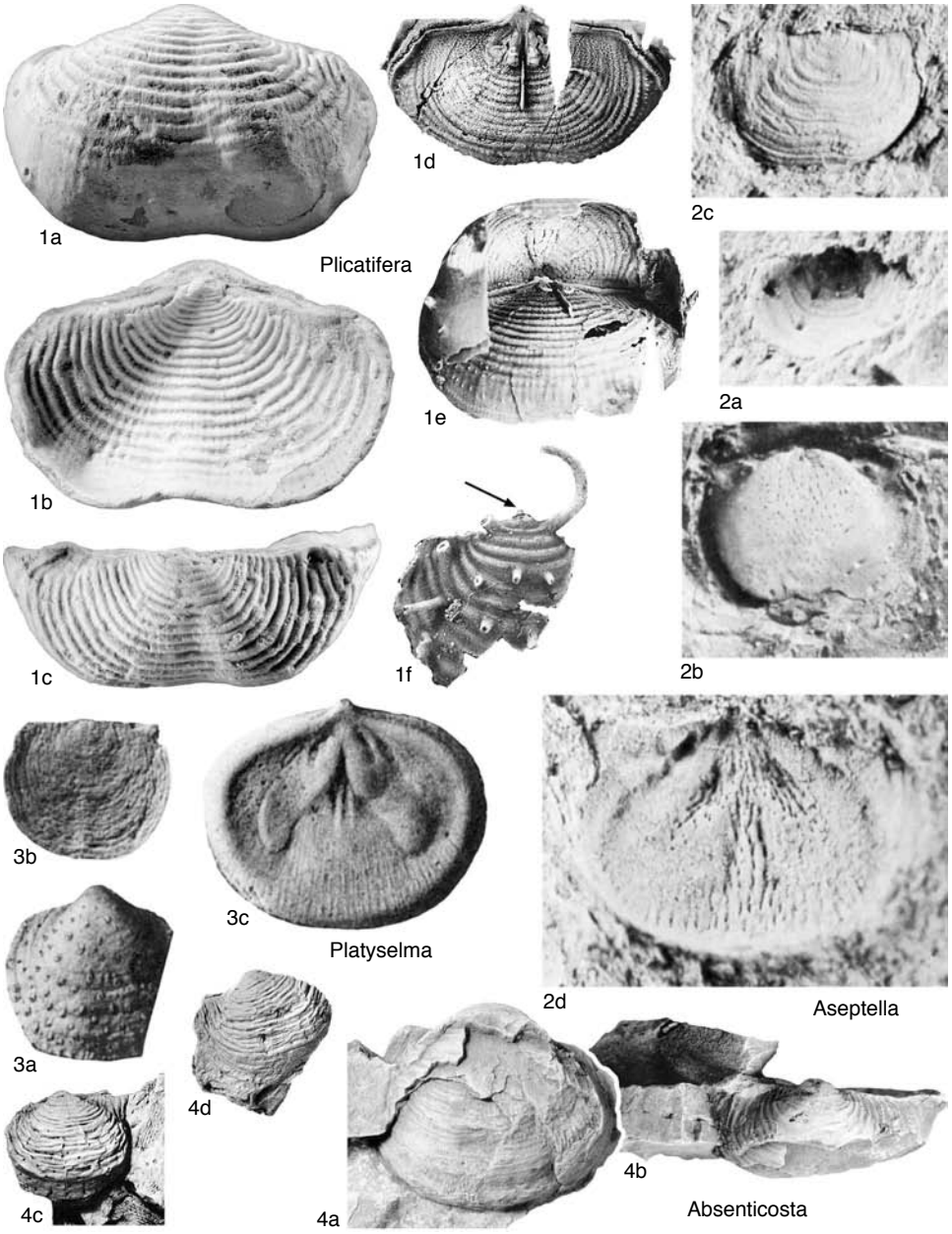

FIG. 297. Productellidae (p. 450–452).

centric lamellae on both valves bearing numerous spines, but only anteriorly on dorsal valve; dorsal complete subperipheral ridge. *Lower Carboniferous (middle Viséan):* USA.——FIG. 298,*2a–e.* **C. perlamellosa,* middle Viséan, Missouri; *a,* holotype viewed ventrally, USNM 120637, ×1; *b,c,* anteriorly, laterally, USNM 120637, ×2; *d,* dorsal valve exterior, ×2; *e,* dorsal valve interior, ×2 (Gordon, 1966).

Ferganoproductus GALITSKAYA, 1977, p. 33 [**Productus ferganensis* JANISCHEWSKY, 1918, p. 41; OD]. Rugae narrow, irregular posteriorly, forming some reticulation with spine bases; spines fine covering ventral valve, plus rows near hinge, at flanks, rarely and

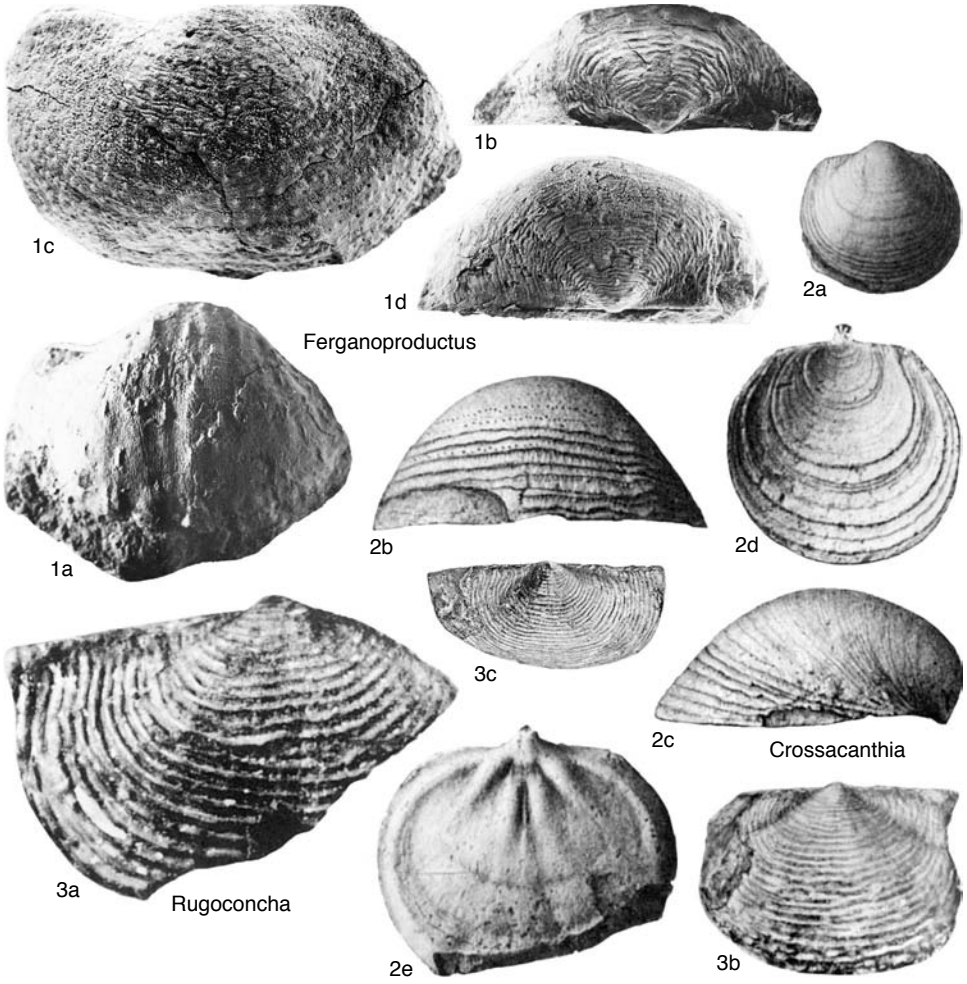

FIG. 298. Productellidae (p. 450–452).

thicker on dorsal valve. *Carboniferous (upper Viséan–Serpukhovian):* eastern Europe, Asia.——FIG. 298,*1a–d. *F. ferganensis* (JANISCHEWSKY), Serpukhovian, Kirghizia; *a,b,* ventral exterior viewed ventrally, posteriorly, ×1; *c,d,* external mold of dorsal valve viewed dorsally, posteriorly, ×1 (Galitskaya, 1977).

Platyselma GORDON, 1966, p. 575 [**P. echinatum;* OD]. Planoconvex with moderately deep corpus cavity; weak lamellae on both valves, spines in weak concentric bands confined to ventral valve (or perhaps fine ones on dorsal valves); strong subperipheral ridges. *Lower Carboniferous (middle Viséan):* southern USA.——FIG. 297,*3a–c. *P. echinatum,* middle Viséan, Oklahoma; *a,* incomplete ventral valve exterior, ×2; *b,* dorsal valve exterior, ×1; *c,* dorsal valve interior, ×2 (Gordon, 1966).

?Rugoconcha JIN & SUN, 1981, p. 132 [**Plicatifera chaoi* GRABAU, 1936, p. 171; OD]. Resembles *Plicatifera,* but seemingly lacking trails, with rugae covering ventral valve; small cicatrix; ginglymus may be present. *Upper Carboniferous (lower Bashkirian):* southern China.——FIG. 298,*3a–c. *R. chaoi* (GRABAU), lower Bashkirian, Guangxi; *a,* ventral valve exterior (holotype No. 5384 lost during WWII; neotype, NIGP 48674, held at Nanjing Institute of Geology & Paleontology), ×2; *b,c,* ventral valve exterior viewed ventrally, posteroventrally, ×1 (Grabau, 1936).

Tribe LEVIPUSTULINI Lazarev, 1985

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, herein, *ex* Levipustulinae LAZAREV, 1985, p. 72]

Dorsal valves with short trails, corpus cavity variable; rugae weak or lacking but spines numerous with pustulose bases, commonly

on both valves, but lost dorsally in Permian; marginal structures, peripheral cavities reduced or absent. *Lower Carboniferous (upper Viséan)–Lower Permian (Kungurian).*

Levipustula MAXWELL, 1951, p. 10 [**L. levis;* OD]. Gently concavoconvex profile, shallow to moderate corpus cavity; pustulose quincuncial spine bases covering ventral valve, spines long, slender, including on ears; lateral ridges short. *Carboniferous (Serpukhovian, ?Bashkirian):* Australia, South America.——FIG. 299,*3a–c. *L. levis; a,b,* holotype, dorsal valve external mold, latex replica of ventral valve exterior, Moscovian, Queensland, UQF 11900a,b, ×1.5 (new); *c,* latex replica of dorsal valve interior, New South Wales, ×2 (Muir-Wood & Cooper, 1960).

Bulahdelia ROBERTS in ROBERTS, HUNT, & THOMPSON, 1976, p. 213 [**B. myallensis;* OD]. Ventral spine row near hinge, elongate spine bases posteriorly, lacking anteriorly where spines concentrically arranged; dorsal spines anteriorly only on lamellose bands; cardinal process pit present. *Lower Carboniferous (upper Viséan):* Australia.——FIG. 299,*1a–e. *B. myallensis,* upper Viséan, New South Wales; *a,* holotype, latex replica of ventral valve exterior, AMF 57742, ×1.5; *b,* internal mold of ventral valve interior, ×1.5; *c,* latex replica of dorsal valve exterior, ×1.5; *d,* latex replica of dorsal valve interior, ×1.5; *e,* latex replica of dorsal valve interior, ×1.5 (Roberts, Hunt, & Thompson, 1976).

Impiacus LAZAREV & SUUR'SUREN in AFANASJEVA & others, 1988, p. 53 [**I. dzhinsetuensis;* OD] [=*Nudymia* LAZAREV, 1990, p. 93 (type, *Bailliena nudymiensis* SARYTCHEVA, 1977, p. 116)]. Medium to large shells; corpus depth variable; rugae weak, irregular; spines varied on both valves, with increasing density on ears in stratigraphically younger species; cardinal ridges diverge from hinge laterally, may extend as ear baffles. *Lower Carboniferous (upper Viséan):* northeastern Asia.——FIG. 299,*2a–c. *I. dzhinsetuensis,* upper Viséan, Gobi Altai, Mongolia; *a,b,* ventral valve internal mold viewed posteriorly, anteriorly, ×1 (new); *c,* dorsal valve exterior, ×1 (new).——FIG. 299,*2d,e. I. arateliensis* LAZAREV, upper Viséan, Ara-Teli-Gol River; *d,* holotype, external mold of ventral valve, PIN 3385/1250, ×1; *e,* incomplete dorsal valve interior, ×2 (Lazarev, 1991).

Jakutoproductus KASCHIRTZEV, 1959, p. 28 [**Marginifera verchoyanica* FREDERICKS, 1931, p. 211; OD]. Medium size, transverse, with well-differentiated ears; ventral disk weakly convex, dorsal disk almost flat; rugae irregular on corpus of both valves, commonly undulose; spine bases scattered ventrally, elongate posteriorly, rounded and concentrically arranged on trail; cardinal process pit separates median septum; lateral ridges in both valves, dorsally continuous as weak marginal ridge. *Lower Permian (Asselian–Kungurian):* northern Canada, Siberia, Mongolia, northern Asia.——FIG. 300,*1a–e. *J. verchoyanica* (FREDERICKS), ?Sakmarian–Artinskian, northeastern Russia, Verkhoyan; *a,b,* lectotype, abraded ventral valve viewed ventrally, laterally, TsNIGRA 45/10902, selected by SOLOMINA, 1981, ×1 (new); *c,d,* shell viewed ventrally, laterally, ×1; *e,* dorsal valve internal mold, ×1 (Solomina, 1981).

Lanipustula KLETS, 1983, p. 75[71] [**Pustula baicalensis* MASLENNIKOV, 1960, p. 341; OD]. Similar to *Levipustula,* but with dense dorsal spines; cardinal ridges, buttress plates. *Lower Carboniferous (?upper Viséan)–upper Upper Carboniferous:* Russia, Transbaikal, Mongolia.——FIG. 300,*2a–d. *L. baicalensis* (MASLENNIKOV), Upper Carboniferous, Transbaikalia; *a,* neotype, ventral valve exterior, PIN 3979/1, ×1; *b,* ventral valve internal cast, ×2; *c,* dorsal valve external mold, ×3; *d,* dorsal valve internal cast, ×3 (Klets, 1983).

Onopordumaria WATERHOUSE in BAMBER & WATERHOUSE, 1971, p. 205 [**O. punctura;* OD]. Poorly known, resembles *Levipustula,* but has more, thinner ventral spines, swollen dorsal spine bases; dorsal interior with strong endospines anteriorly. *Upper Carboniferous (middle Moscovian):* Canada.——FIG. 301*a–c. *O. punctura,* middle Moscovian, Yukon; *a,* holotype, incomplete ventral valve exterior, GSC 26396, ×1; *b,* broken ventral valve internal casts, ×1; *c,* dorsal valve internal cast, ×1 (Bamber & Waterhouse, 1971).

Piatnitzkya TABOADA, 1993, p. 591 [**P. borrelloi;* OD]. Small, resembles *Jakutoproductus,* but lacks concentric rugae, strong rounded spine bases on trail. [The presence of fine ribbing would place this genus in the Auriculispininae]. *Lower Permian (Asselian):* Argentina.——FIG. 300,*4a–d. *P. borrelloi,* Permian, Rio Genoa Formation, Chubat Province; *a,* ventral valve exterior, ×1.5; *b,* dorsal valve external mold, ×2; *c,d,* latex replicas of dorsal valve interiors, ×1.5 (Taboada, 1993).

Verchojania ABRAMOV, 1970, p. 112 [**Jakutoproductus cheraskowi* KASCHIRTZEV, 1959, p. 30; OD]. Similar to *Jakutoproductus* but without dorsal spines, with weakly developed or lacking concentric rugae; ventral sulcus variable. *Upper Carboniferous (Bashkirian–Moscovian):* northern Asia.——FIG. 300,*3a–c. *V. cheraskowi* (KASCHIRTZEV), Bashkirian–Moscovian, Yakutsk; *a,b,* internal mold of ventral valve viewed ventrally, anterolaterally, ×1 (new); *c,* ventral valve, shell missing umbonally, viewed posteriorly, ×1 (Abramov, 1970).

Tribe LEVITUSIINI Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, herein, *ex* Levitusiinae MUIR-WOOD & COOPER, 1960, p. 295]

Relatively large shells with long trails, moderate to deep corpus cavities; ribbing absent or weak fine radial striations; rugae, spines weak, sparsely developed; spine row anterior to ears, commonly a ventral median row on weak ridge; weak cardinal ridges, no marginal ridges. *Lower Carboniferous (Tournaisian–upper Viséan).*

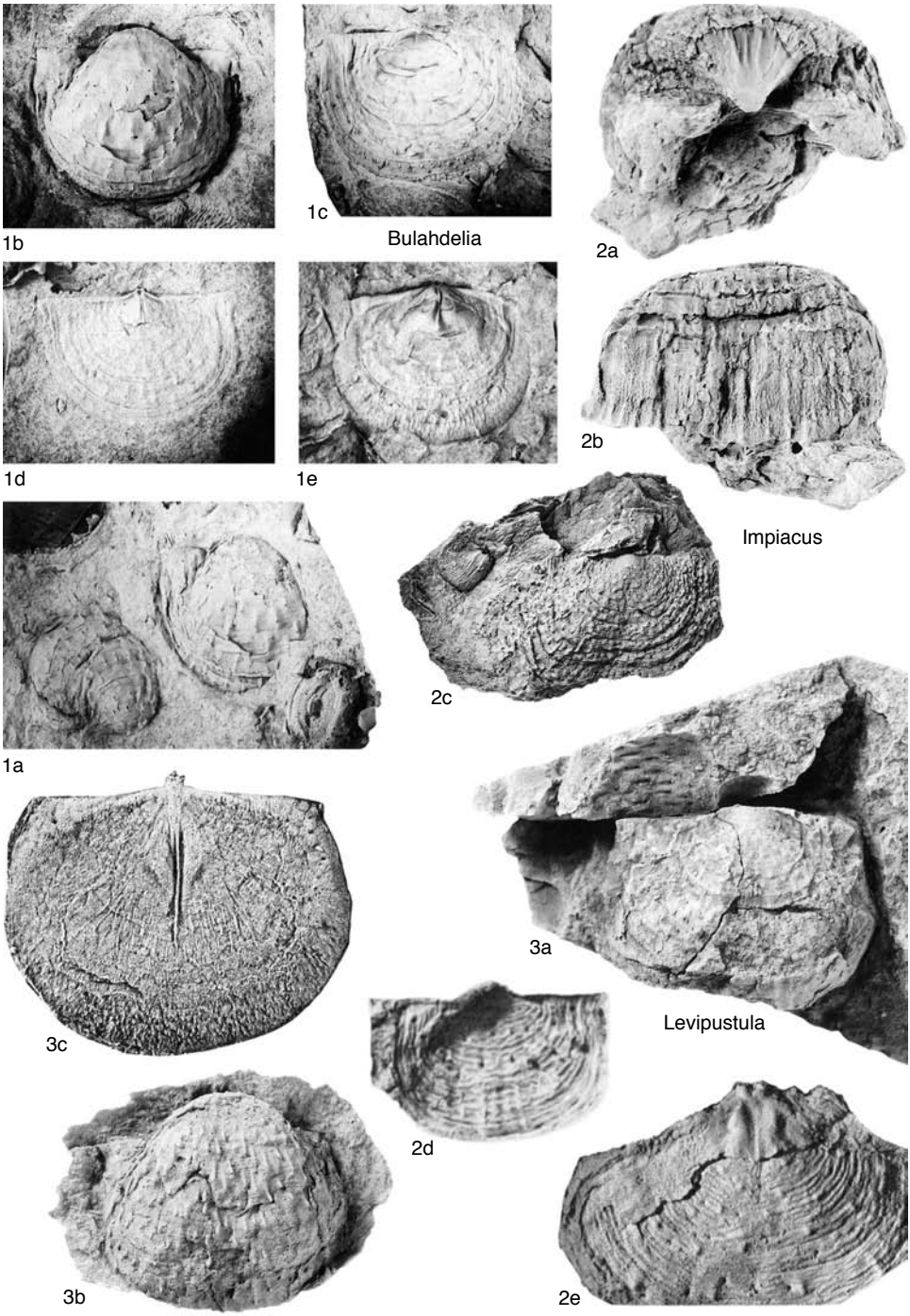

FIG. 299. Productellidae (p. 453).

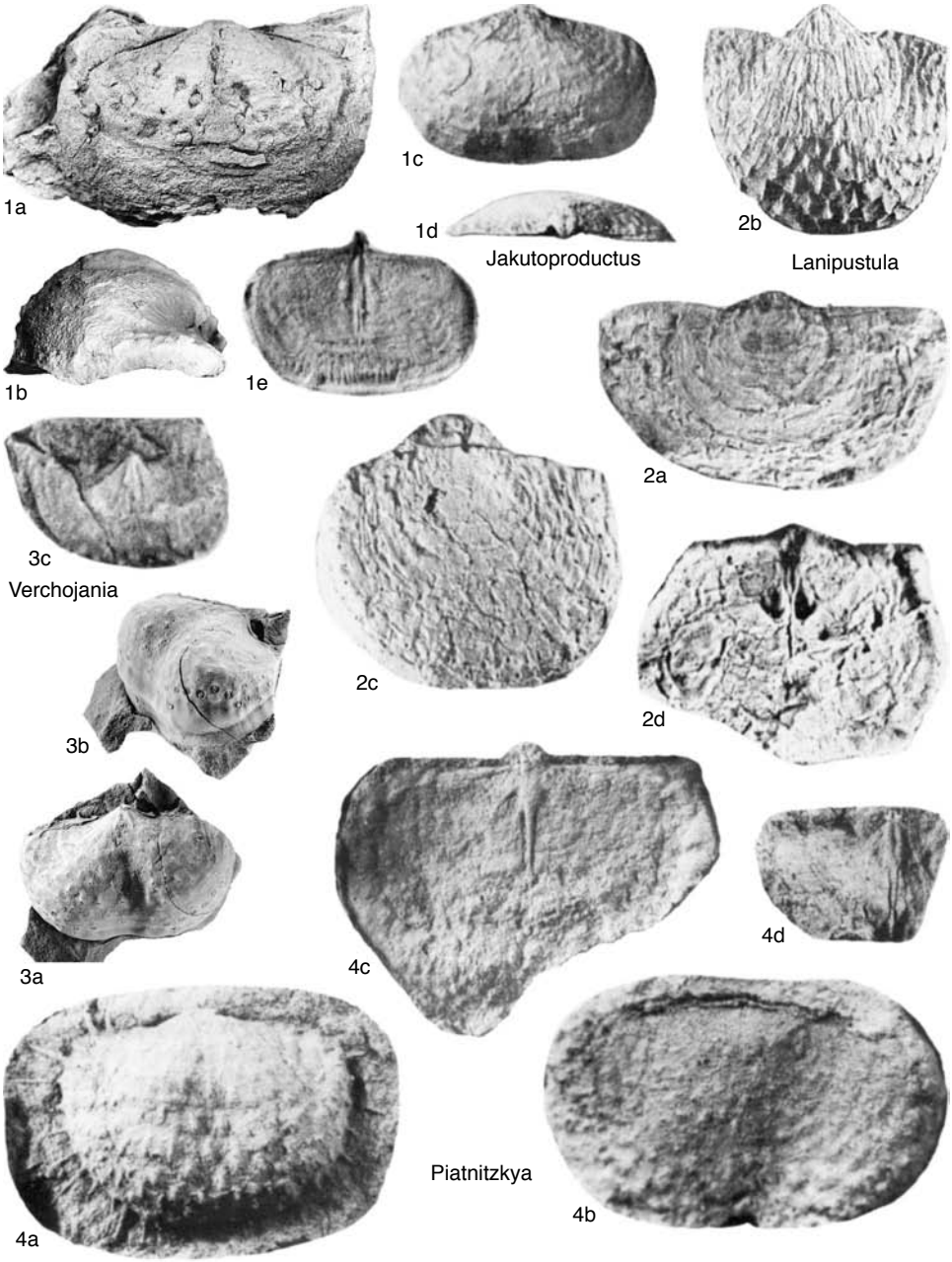

FIG. 300. Productellidae (p. 453).

Levitusia MUIR-WOOD & COOPER, 1960, p. 295 [**Productus humerosus* J. SOWERBY, 1822 in 1821–1822, p. 21; OD; =*P. christiani* DE KONINCK, 1847a, p. 274]. Commonly large with thick walled ventral valve, trail long, spreading; fine radial ornament on some species, may also have median ridge with

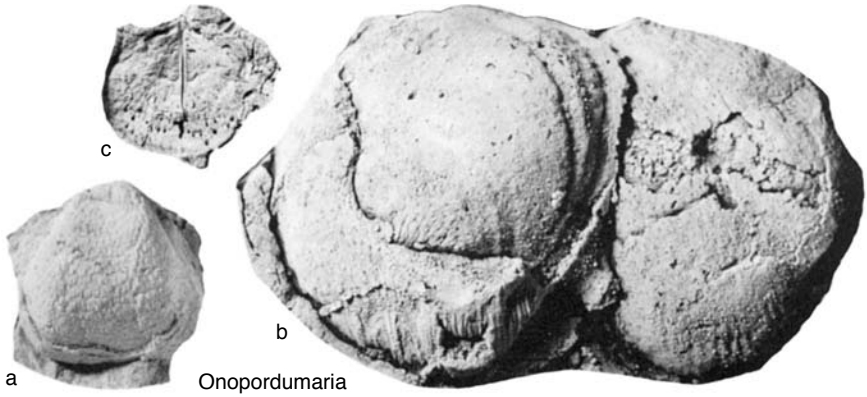

FIG. 301. Productellidae (p. 453).

spines; corpus cavity shallow; ventral brachial pits in some species. *Lower Carboniferous (Viséan):* Europe, Ural Mountains, ?Middle Asia (Kirghizia).——FIG. 302*a–f. *L. humerosa* (J. SOWERBY); *a,b,* holotype, ventral valve internal mold viewed anteriorly, laterally, lower Viséan, Derbyshire, British Isles, BMNH B 60959, ×1; *c,d,* ventral valve exterior viewed anteriorly, laterally, Staffordshire, ×0.75 (Brunton, 1979); *e,* dorsal valve interior, Staffordshire, ×1; *f,* ventral valve exterior viewed posteroventrally, Visé, Belgium, ×1 (Muir-Wood & Cooper, 1960).——FIG. 302*g.* Specimen called *P. christiani* by DE KONINCK; detail anteromedianly, showing median spines, fine radial ornament, Visé, Belgium, UPS D812, ×2.5 (Brunton, 1979).

Acanthoplecta MUIR-WOOD & COOPER, 1960, p. 170 [**Producta mesoloba* PHILLIPS, 1836, p. 215; OD]. Medium sized, around 30 mm wide; concavoconvex with long trails, may have gutter; commonly weak median fold bearing spines, dorsal sulcus; other spines scattered; body cavity shallow to deep. *Lower Carboniferous (Viséan):* Eurasia, northern Africa.——FIG. 303,*1a–f. *A. mesoloba* (PHILLIPS); *a,* lectotype, ventral valve exterior viewed anteriorly, Asbian, Yorkshire, BMNH B427, ×1.5; *b,* lectotype, ventral valve exterior viewed anterolaterally, Asbian, Yorkshire, ×1; *c,* ventral valve exterior viewed posteriorly, Asbian, Yorkshire, ×1 (new); *d,* complete shell viewed dorsally, Asbian, Yorkshire, ×1 (Muir-Wood & Cooper, 1960); *e,f,* silicified dorsal valve with gutter viewed ventrally, laterally, Fermanagh, ×1.25 (Brunton, 1966).

Admodorugosus BRUNTON & MUNDY, 1993, p. 111 [**A. cracoensis;* OD]. Small to medium sized; prominent rugae covering entire valves, no ribbing; larger spines in rows near hinge and medianly. *Lower Carboniferous (Asbian):* western Europe.——FIG. 303,*2a–e. *A. cracoensis; a,b,* holotype, shell with broken ventral valve, showing some of dorsal valve, viewed ventrally, posteriorly, Asbian, Yorkshire, BMNH BD 2447, ×2; *c,* oblique view of shell with ventral trail missing, Staffordshire, ×2; *d,* anterolateral view of complete ventral valve, Staffordshire, ×2; *e,* anterior view of ventral valve showing median spines, Staffordshire, ×2 (Brunton & Mundy, 1993).

Geniculifera MUIR-WOOD & COOPER, 1960, p. 187 [**Avonia boonensis* BRANSON, 1938, p. 40; OD]. Small, around 12 mm wide; planoconvex, deep corpus plus simple trails; rugae posteriorly on disks, trails smooth; spines few, scattered on ventral valve. *Lower Carboniferous (Hastarian–Viséan):* North America, Europe.——FIG. 304,*1a–d. *G. boonensis* (BRANSON), Hastarian, New Mexico; *a–c,* ventral valve exterior viewed ventrally, posteriorly, laterally, ×2; *d,* dorsal valve interior, ×3 (Muir-Wood & Cooper, 1960).——FIG. 304,*1e. G. keyserlingiana* (DE KONINCK), Viséan, Visé, Belgium; latex replica of dorsal valve interior, ×3.5 (Brunton & Mundy, 1993).

Kadraliproductus GALITSKAYA, 1977, p. 36 [**Productus (Plicatifera) kadralensis* GLADTCHENKO, 1955, p. 15; OD]. Posterior nodose reticulation of impersistent median ribbing with rugae; spines at hinge, scattered ventrally; corpus deep. *Lower Carboniferous (upper Tournaisian):* Kirghizia, western Europe.——FIG. 303,*3a–d. *K. kadralensis* (GLADTCHENKO), upper Tournaisian, Kirghizia; *a,b,* holotype, ventral valve viewed posteroventrally, anteriorly, Inst. Geol. 81/3, ×1; *c,* complete ventral valve viewed laterally, ×1; *d,* shell with part of ventral valve missing, viewed anteriorly showing deep corpus, ×1 (Galitskaya, 1977).

Spinorugifera ROBERTS, 1976, p. 50 [**S. chichesterensis;* OD]. Small; gently concavoconvex profile without clear trails; entirely rugose, slightly lamellose ventrally, with spines near hinge, scattered on ventral rugae, spines commonly lacking dorsally; lateral ridges short. *Lower Carboniferous (upper Viséan):* Australia.——FIG. 304,*2a–d. *S. chichesterensis,* upper Viséan, New South Wales; *a,b,* holotype, latex replicas of ventral valve exterior, dorsal valve exterior, AMF 57025a,b, ×2; *c,d,* latex replicas of dorsal valve exterior, interior, ×2 (Roberts, 1976).

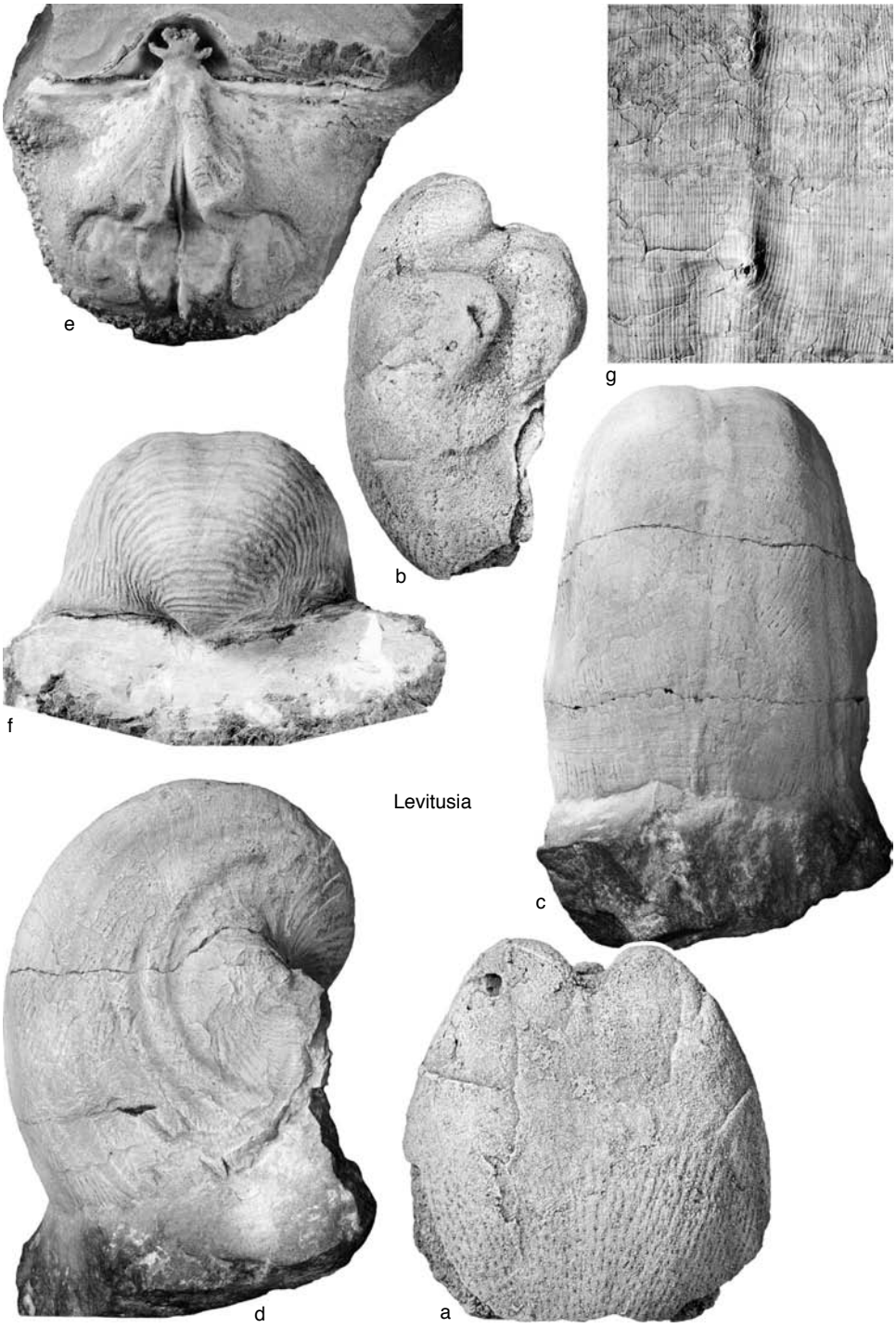

FIG. 302. Productellidae (p. 455–456).

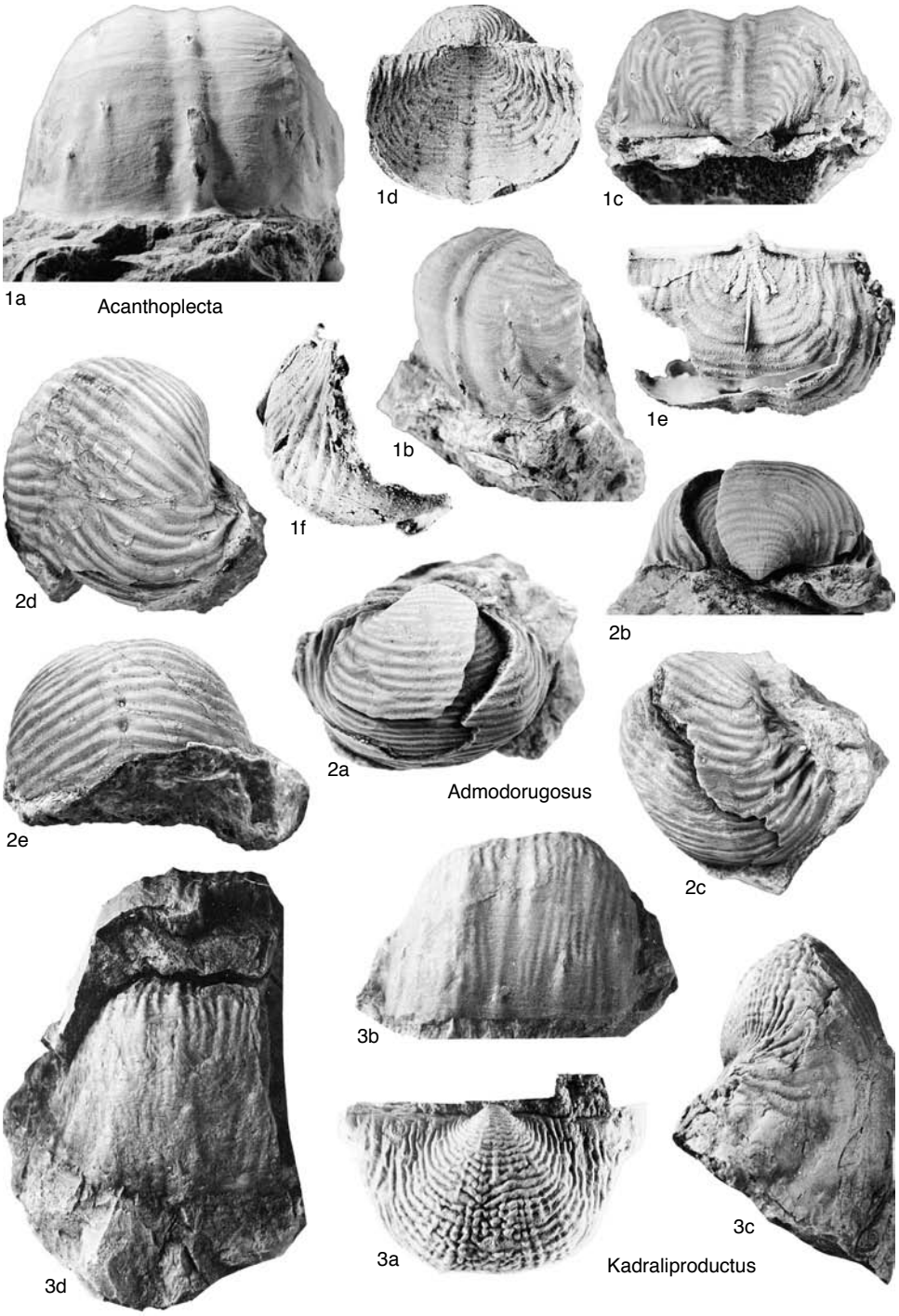

FIG. 303. Productellidae (p. 456).

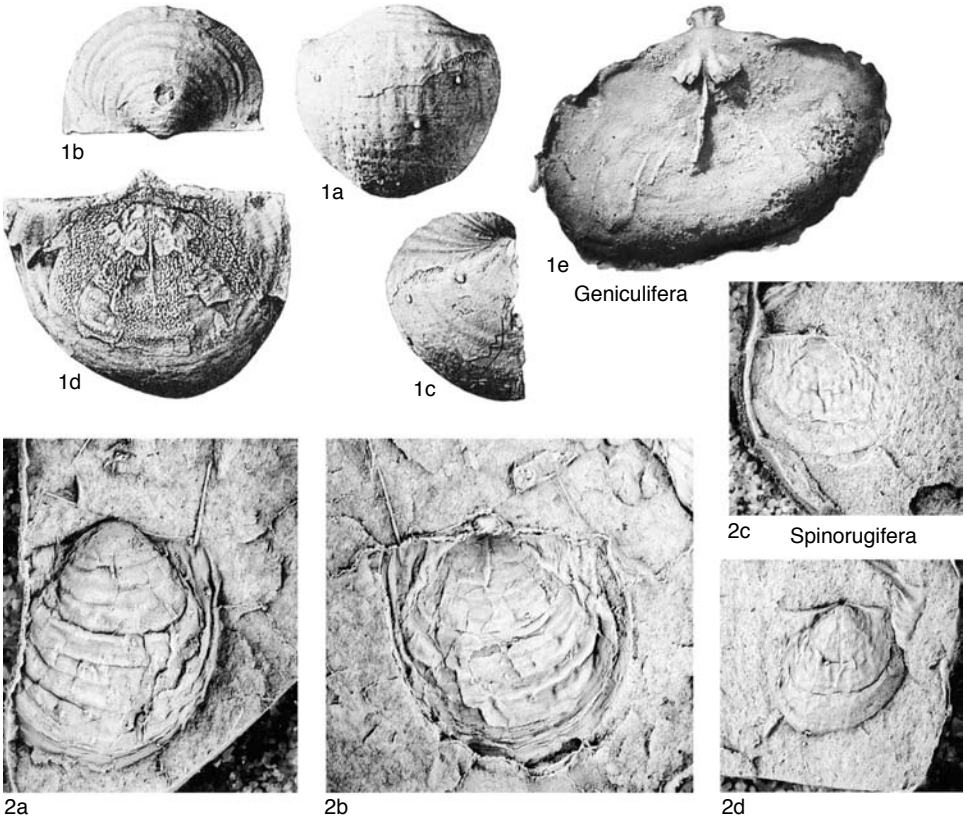

FIG. 304. Productellidae (p. 456).

Tribe RUGAURINI Lazarev, 1990

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, herein, *ex* Rugaurinae LAZAREV, 1990, p. 88]

Corpus cavity shallow; trail absent or very short; no ribbing, dense spines covering ventral valve, rarely on dorsal valves anteriorly; teeth in oldest taxa; no ear baffles or submarginal ridges. *Upper Devonian (upper Famennian)–Lower Carboniferous (upper Viséan).*

Rugauris MUIR-WOOD & COOPER, 1960, p. 193 [**R. paucispina;* OD]. Medium size; semicircular outline, gently concavoconvex profile; rugae numerous, narrow, covering disks; fine low-angled spines cover ventral valve; dorsal valve dimpled, few spines; lateral ridges subparallel to hinge. *Lower Carboniferous (Hastarian):* USA, Russia, eastern Australia, Canada, ?San Salvador.——FIG. 305,*1a–f.* **R. paucispina,* Hastarian, Iowa; *a–d,* holotype, ventral, anterior, posterior, lateral views of ventral valve, USNM 79477a, ×1; *e,* replica of dorsal valve exterior, ×1; *f,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Carringtonia BRUNTON & MUNDY, 1986, p. 2 [**Productus carringtoniana* DAVIDSON, 1863, p. 274; OD]. Transverse, markedly but irregularly rugose, ventral spines only, at hinge, widely on rugae. *Lower Carboniferous (upper Viséan):* western Europe.——FIG. 305,*2a–d.* **C. carringtoniana* (DAVIDSON); *a,* lectotype, ventral valve exterior, Asbian, Staffordshire, BMNH B 5743, ×1; *b,* external mold of dorsal valve showing dimples of ventral hinge spines, Asbian, Staffordshire, ×1.5; *c,d,* posterolateral, dorsal views of shell, Yorkshire, ×1.5 (new).

Iniproductus LAZAREV, 1990, p. 88 [**Pustula ?inica* SARYTCHEVA in BEZNOSSNOVA & others, 1962, p. 151; OD]. Resembles *Rugauris,* but larger, rugae less regular, no dorsal spines; two or three rows of thicker spines near hinge, elongate quincuncial spine bases except on trails where spine bases small, concentric; cardinal ridges short. *Upper Devonian (upper Famennian):* Russia.——FIG. 306*a–e.* **I.*

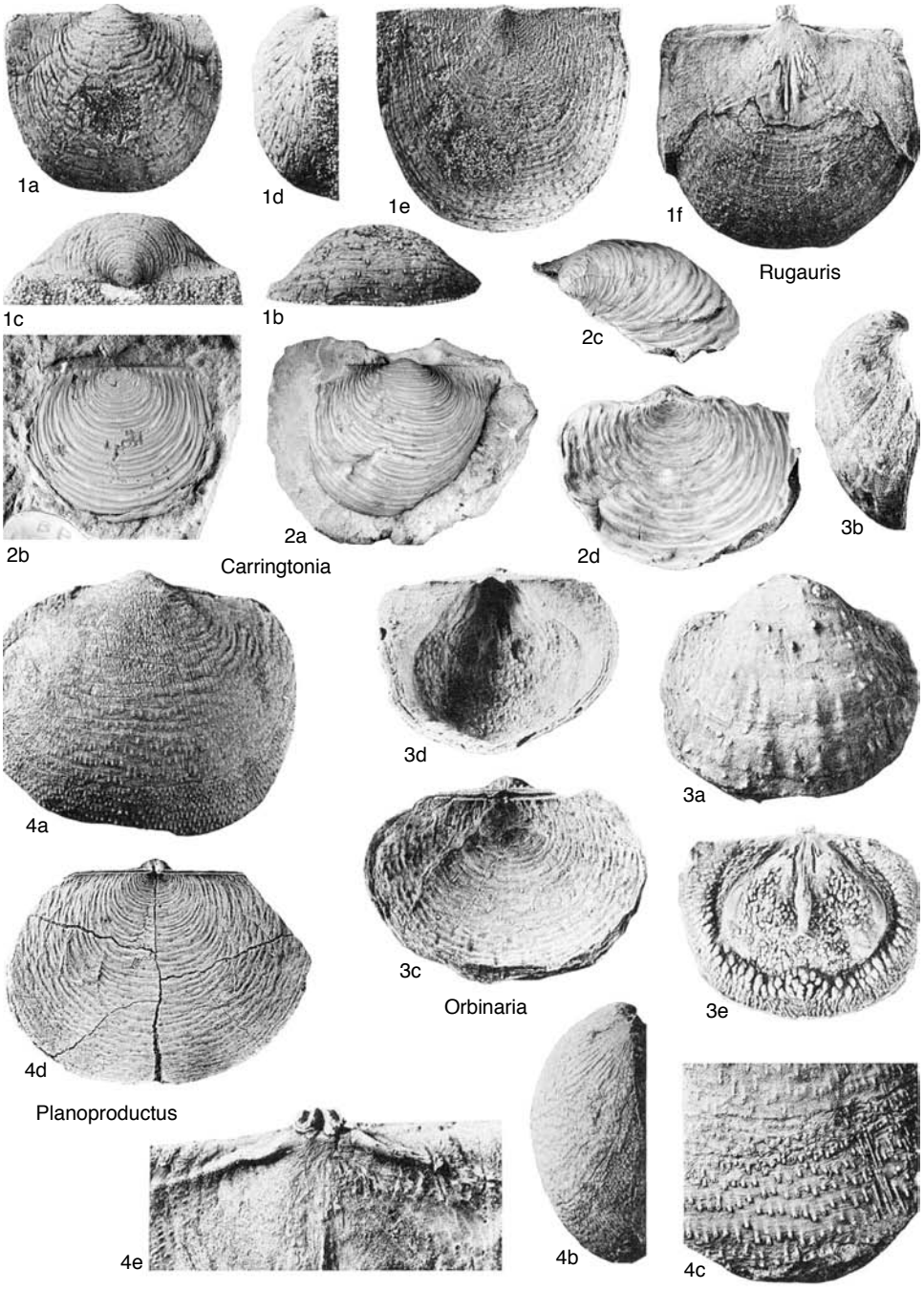

FIG. 305. Productellidae (p. 459–461).

inicus (SARYTCHEVA), upper Famennian, Kuzbass; *a,b,* ventral, lateral views of ventral valve, ×1; *c,* dorsal exterior of incomplete shell, ×1; *d,* spines extending from near lateral margin of ventral valve, ×2.5; *e,* incomplete dorsal valve interior, ×1 (Sarytcheva & others, 1963).

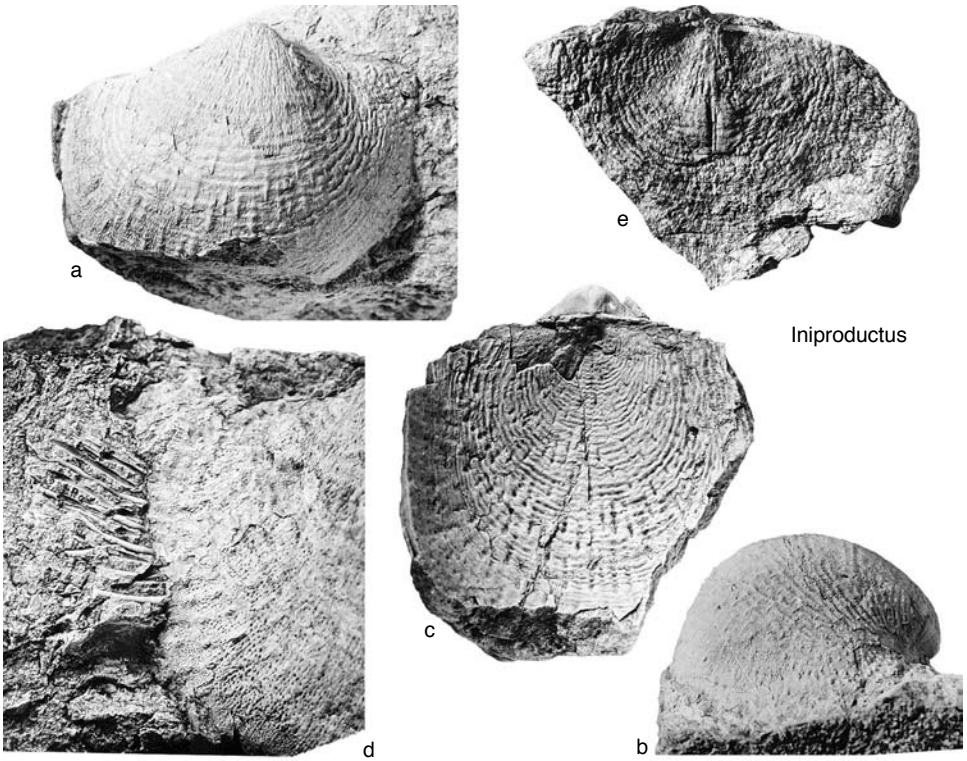

FIG. 306. Productellidae (p. 459–460).

Orbinaria MUIR-WOOD & COOPER, 1960, p. 149 [**Productella pyxidata* HALL, 1858a, p. 498; OD]. Weakly concavoconvex profile; concentric ornament, especially on dorsal valve; dorsal spines sparse, fine; ventral spines with slight pustules; teeth minute; dorsal interior with strongly papillose subperipheral ridge. *Upper Devonian (upper Famennian), Lower Carboniferous (?Hastarian):* North America, ?Europe, ?northern Africa.——FIG. 305,*3a–e.* **O. pyxidata* (HALL), upper Famennian, possibly to lower Hastarian, Louisiana Limestone, Missouri; *a,* ventral valve exterior, ×2; *b,c,* lateral view, dorsal view of shell, ×2; *d,e,* ventral valve interior, dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Planoproductus STAINBROOK, 1947, p. 310 [**Productella hillsboroensis* KINDLE, 1909, p. 19; OD]. Medium sized; rugae weak ventrally, stronger dorsally; spines on ventral valve only, fine, numerous with short ridges; lateral ridges short, divergent. *Upper Devonian (upper Famennian):* southern USA, France, ?Japan.——FIG. 305,*4a–e.* **P. hillsboroensis* (KINDLE), uppermost Famennian, New Mexico; *a,b,* ventral valve exterior viewed ventrally, laterally, ×1; *c,* detail of ornament, ×2; *d,* dorsal valve exterior, ×1; *e,* posterior region of dorsal valve interior, ×4 (Muir-Wood & Cooper, 1960).

Tribe SEMICOSTELLINI Nalivkin, 1979

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 927, *ex* Semicostellinae NALIVKIN, 1979, p. 67]

Corpus cavity deep; costae on long trails; lateral, marginal ridges commonly well developed in both valves. *Lower Carboniferous (Tournaisian)–Upper Permian (Kazanian).*

Semicostella MUIR-WOOD & COOPER, 1960, p. 195 [**Avonia oklahomensis* SNIDER, 1915, p. 83; OD]. Rugae weak, with elongated spine bases on ventral disk, clear ribs anteriorly, spines in row on flanks; dorsal valve rugose, sparsely spinose, geniculate with clear ribs on trail; divergent lateral ridges, marginal structures. *Lower Carboniferous (upper Viséan–lower Serpukhovian):* southern USA, Ural Mountains, northern Asia.——FIG. 307,*1a–e.* **S. oklahomensis* (SNIDER), upper Viséan–lower Serpukhovian, Oklahoma; *a–c,* ventral valve viewed ventrally, posteriorly, laterally, ×1; *d,* shell viewed dorsally, ×1; *e,* dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Cinctifera MUIR-WOOD & COOPER, 1960, p. 165 [**Productus medusa* DE KONINCK, 1842, p. 166;

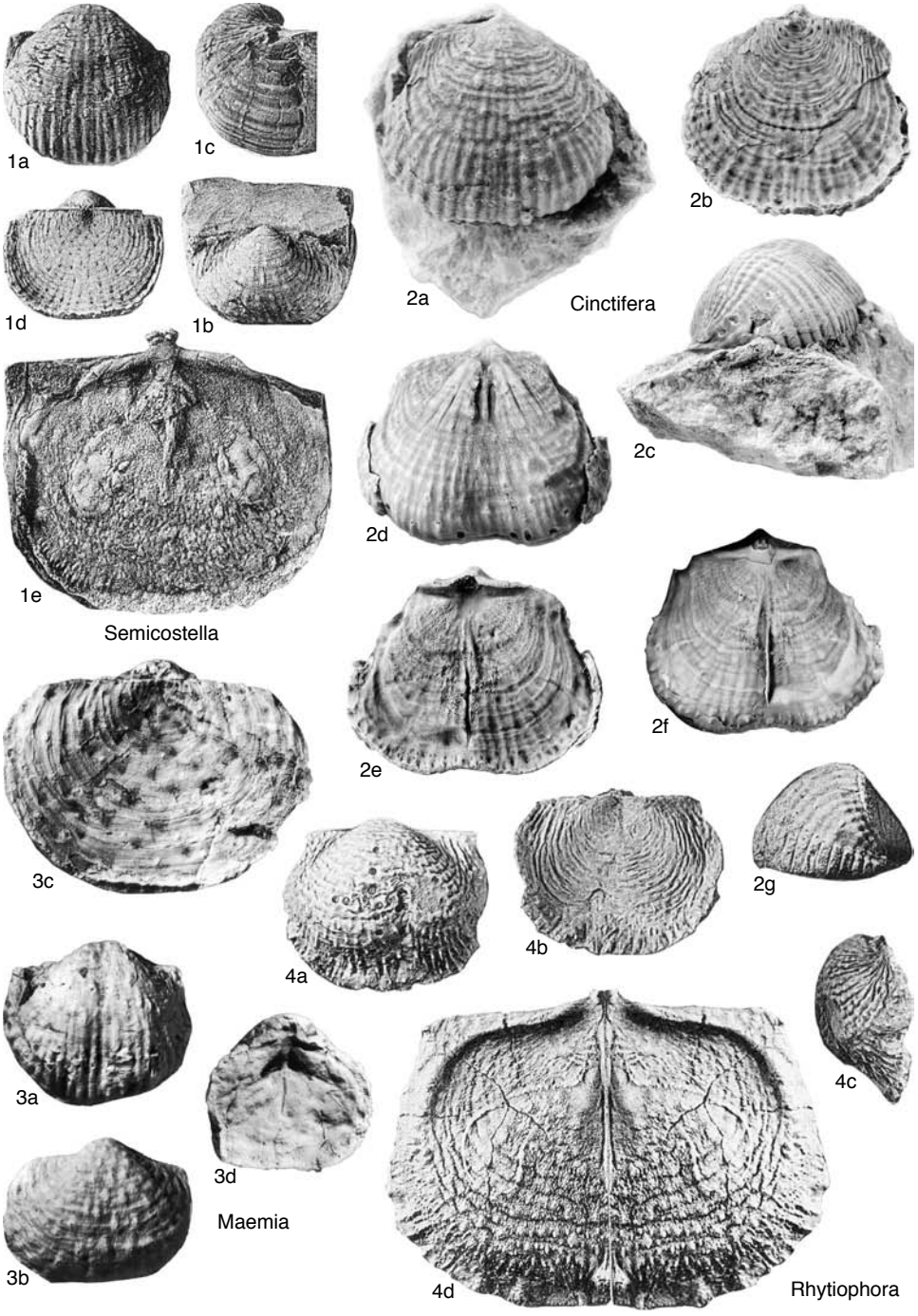

FIG. 307. Productellidae (p. 461–464).

OD]. Ventral valve disk flattened, ribbing complete, other than beaks; cinctures especially at margin of disk, spinose outgrowths from ventral valve margin. *Lower Carboniferous (Viséan):* Europe.——FIG. 307,*2a–g.* **C. medusa* (DE KONINCK); *a–c,* shell viewed ventrally, dorsally, ventral valve viewed later-

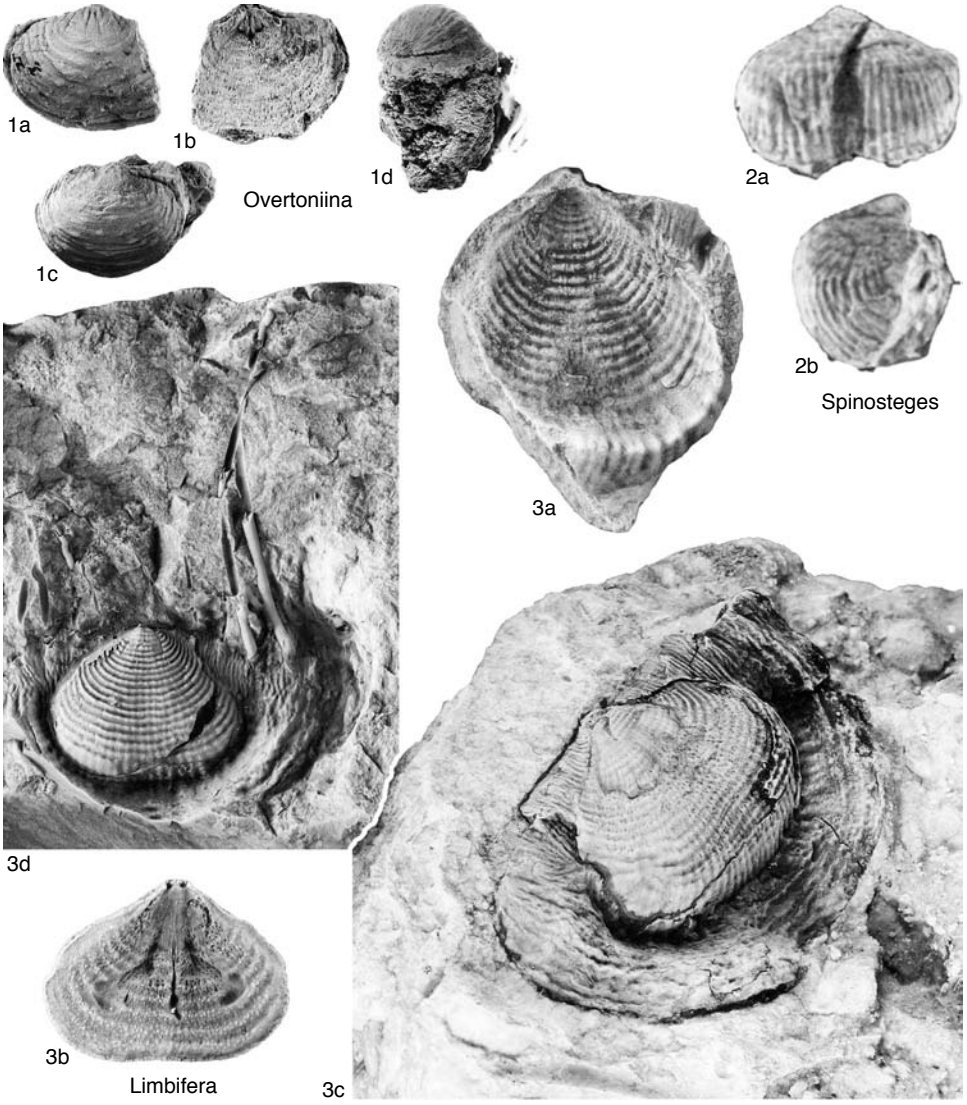

FIG. 308. Productellidae (p. 463–464).

ally, Asbian, Derbyshire, British Isles, ×2; *d–f,* internal mold viewed ventrally, dorsally plus latex replica of dorsal interior, Asbian, Derbyshire, ×2 (new); *g,* ventral valve internal mold showing marginal spines, Visé, Belgium, ×3 (Muir-Wood & Cooper, 1960).

Limbifera BRUNTON & MUNDY, 1988b, p. 69 [**Productus griffithianus* DE KONINCK, 1847b, p. 74; OD]. Small; corpus outline triangular with large flattened ears; weakly concavoconvex with shallow corpus, ventrally geniculated gutter; ribbing entire with rugae posteriorly; paired row of stout attachment spines across ears; lateral ridges, ear baffles strong. *Lower Carboniferous (upper Viséan):* western Europe.——FIG. 308,*3a–d. *L. griffithiana* (DE KONINCK); *a,* lectotype, incomplete internal mold viewed anterodorsally, Viséan, Visé, Belgium, BMNH BD 3376, ×3; *b,* internal mold of dorsal valve, Viséan, Visé, ×3; *c,* oblique view of ventral valve exterior with gutter, Asbian, Yorkshire, ×2; *d,* incomplete ventral valve exterior with posterior attachment spines, Asbian, Yorkshire, ×1.5 (Brunton & Mundy, 1988b).

Maemia LAZAREV in BRUNTON & LAZAREV, 1997, p. 391 [**M. chaykensis;* OD]. Small to medium with rectangular outline; both valves geniculate with moderate to deep corpus cavity; rugae weak on both disks; ribbing on trails only; spines on both valves;

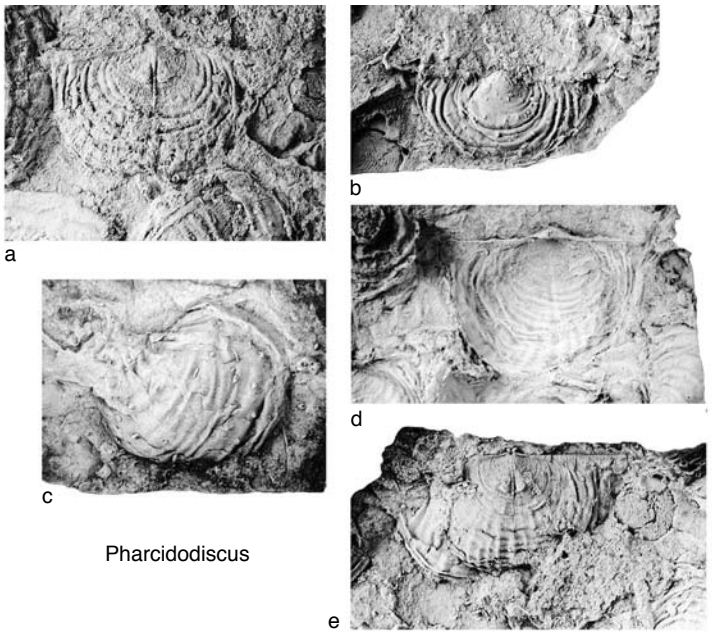

FIG. 309. Productellidae (p. 464).

ventral lateral and marginal ridges weak; dorsal cardinal ridges continue as ear baffles, weak submarginal ridges; adductor scars raised with medianly curving crests. *Upper Carboniferous:* Arctic Russia.——FIG. 307,*3a–c. *M. chaykensis,* upper Bashkirian–lower Kasimovian, Yugorsky Peninsula, Mongolia; *a,* holotype, viewed ventrally, PIN N2802/1168, ×1; *b,* ventral valve exterior, ×1; *c,* dorsal valve exterior, ×2 (Brunton & Lazarev, 1997).——FIG. 307,*3d. M. nana* LAZAREV, upper Moscovian–lower Kasimovian; dorsal valve internal mold, ×2 (Brunton & Lazarev, 1997).

Overtoniina GRUNT in GRUNT & DMITRIEV, 1973, p. 94 [**O. mamazairica;* OD]. Small, planoconvex corpus with geniculation to trails; ventral disk weakly but densely rugose, with rounded spine bases; trail with broad ribs; lateral ridges, median septum short; adductor platforms overhang anteromedianly. *Lower Permian (Artinskian):* Pamir, Afghanistan.——FIG. 308,*1a–d. *O. mamazairica,* Artinskian, southeastern Pamir; *a,b,* holotype, internal mold viewed ventrally, dorsally, PIN 2228/590, ×1; *c,d,* specimen viewed ventrally, laterally, ×1 (Grunt & Dmitriev, 1973).

Pharcidodiscus ROBERTS, 1976, p. 46 [**P. boulderensis;* OD]. Rugae, ribbing weaker than *Semicostella;* ears prominent, corpus cavity moderately deep; spine rows just anterior to hinge; cardinal ridges, but ear baffles absent. *Lower Carboniferous (upper Tournaisian):* Australia.——FIG. 309*a–e. *P. boulderensis,* upper Tournaisian, Queensland; *a,* holotype, latex replica of dorsal valve interior, GSQ F10269, ×1.5; *b,* latex replica of posterior region of ventral valve exterior, ×1.5; *c,* latex replica of anterior region of ventral valve exterior, ×1.5; *d,* latex replica of dorsal valve exterior, ×1.5; *e,* latex replica of dorsal valve interior, ×2 (Roberts, 1976).

Rhytiophora MUIR-WOOD & COOPER, 1960, p. 192 [**Productus blairi* MILLER, 1891, p. 689; OD]. Subquadrate outline; rugae irregular, weak ventromedianly, trail short, ribbed; spine ridges ventrally, especially anteriorly; spines numerous, dorsally only anteriorly; lateral ridges extend to separate ears from corpus. *Lower Carboniferous (middle Hastarian):* USA, Central America, northwestern Australia, ?central China.——FIG. 307,*4a–d. *R. blairi* (MILLER), middle Hastarian, Missouri; *a–c,* ventral, dorsal, lateral views of shell, ×1; *d,* half of dorsal valve interior completed by mirror image, ×2 (Muir-Wood & Cooper, 1960).

Spinosteges LIANG, 1990, p. 155[461] [**S. sinensis;* OD]. Small, outline subquadrate with hinge slightly less than maximum width; ventral disk flattened, trail sulcate; elongate spine bases on ventral disk, relatively fine ribbing on trail; dorsal valve interiors unknown. *Upper Permian (Kazanian):* China.——FIG. 308,*2a,b. *S. sinensis,* Permian, Lengwu Formation, Zhejiang; anteroventral, lateral views, ×2 (Liang, 1990).

Tribe YAKOVLEVIINI Waterhouse, 1975

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 927, *ex* Yakovleviinae WATERHOUSE, 1975, p. 11] [=Inflatiidae SARYTCHEVA in SARYTCHEVA, ed., 1977, p. 102]

Commonly medium sized with thick-shelled ventral valve, moderately deep corpus

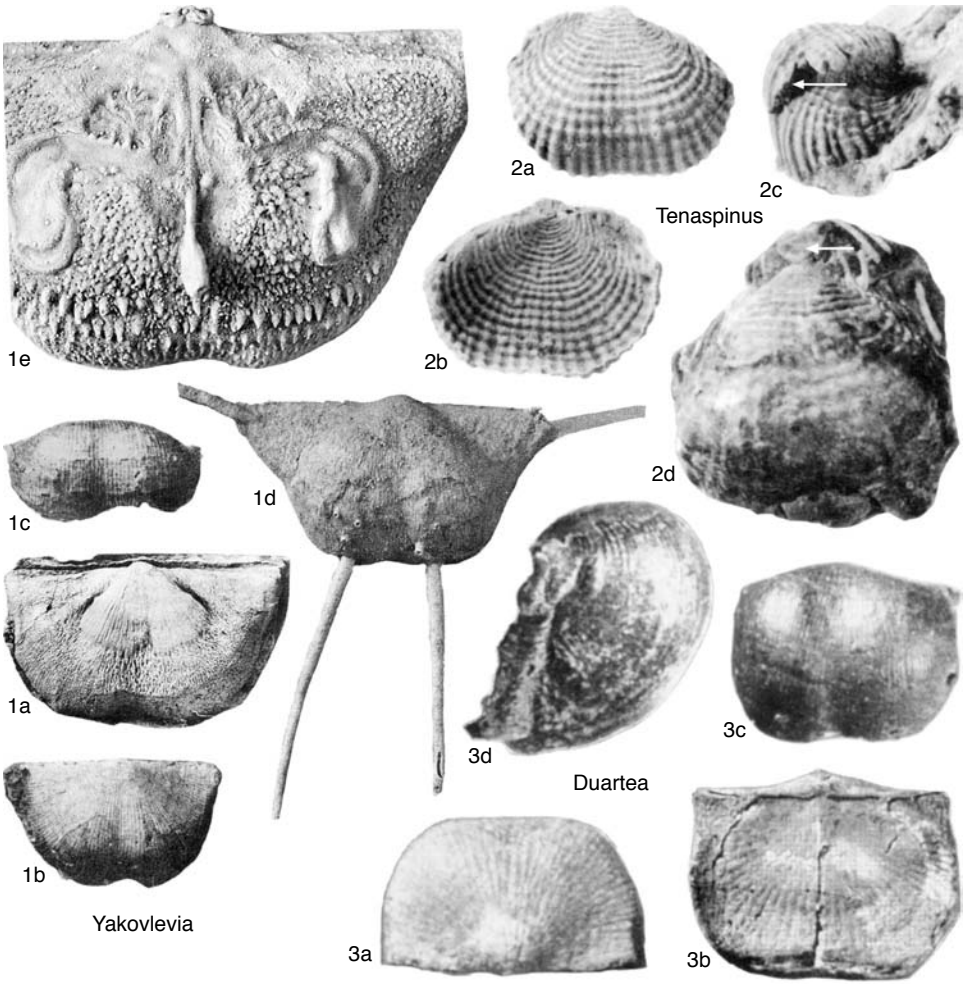

FIG. 310. Productellidae (p. 465–467).

cavity, becoming shallow in younger genera; ribbing on trails and all but posterior regions of corpus, commonly with four to six thick ventral spines; common trend to reduce ear cavities and extend anterior peripheral cavity. *Lower Carboniferous (upper Viséan)–Upper Permian (Kazanian).*

Yakovlevia FREDERICKS, 1925, p. 7 [**Y. kaluzinensis;* OD] [=*Muirwoodia* LICHAREW, 1947, p. 188, *partim* (type, *Productus mammatus* KEYSERLING, 1846, p. 206; OD)]. Medium to large, outline pentagonal to subquadrate; ventral profile with flattened disk, strong geniculation, long trail; corpus cavity shallow; commonly median sulcus, starting posteriorly on disk; ribbing fine, weak; spines in rows of increasing size near hinge, plus few others, commonly four symmetrically placed; muscle fields strongly impressed; cardinal process sessile, broad; lateral ridges close to hinge, strongly angled separating small ears; anterior disk thickened or with endospines. *Lower Permian (Sakmarian)–Upper Permian (Kazanian):* Siberia, Arctic regions, Mongolia, China, Japan, USA.——FIG. 310,*1a.* **Y. kaluzinensis,* upper Lower Permian, eastern Siberia; ventral valve internal mold, ×0.7 (Wiman, 1914).——FIG. 310,*1b,c. Y. mammata* (KEYSERLING), Lower Permian, northern Russia; ventral valve viewed ventrally, anteriorly, ×1 (Licharew, 1947).——FIG. 310,*1d,e. Y. multistriata* (MEEK), Lower Permian, Texas; *d,* ventral valve exterior, ×1; *e,* dorsal valve interior, ×2 (Licharew, 1947).

Duartea MENDES, 1959, p. 58 [**Productus batesianus* DERBY, 1874, p. 54; OD] [=*Muirwoodia* LICHAREW, 1947, p. 188, *partim; Paramuirwoodia* ZHANG in ZHANG & others, 1983, p. 298]. Resembles

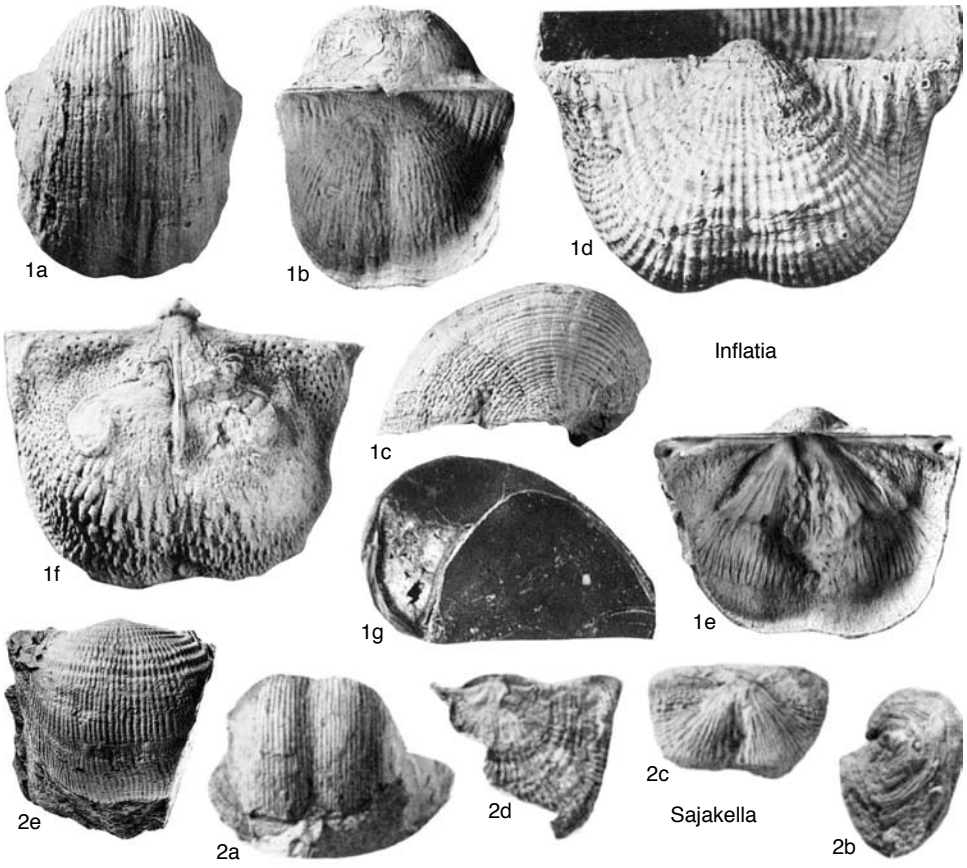

FIG. 311. Productellidae (p. 466–467).

Yakovlevia externally, but moderately deep corpus; spines in weak row separating ears, slight posterior reticulation, ribs become weak anteriorly. *Upper Carboniferous:* South America, Eurasia.——FIG. 310,*3a–d.* **D. batesiana* (DERBY), lower part of Upper Carboniferous, Para Province, Brazil; *a,b,* shell viewed posteriorly, dorsally, ×1.5; *c,* ventral valve exterior, ×1; *d,* lateral view of ventral valve, ×1 (Mendes, 1959).

Inflatia MUIR-WOOD & COOPER, 1960, p. 226 [**Productus inflatus* MCCHESNEY, 1860, p. 40; OD] [=*Adairia* GORDON, HENRY, & TREWORGY, 1993, p. 20 (type, *A. adairensis* DRAKE, 1897, p. 402)]. Outline somewhat elongate with long trail, corpus deep; spines in row diverging from hinge, sparsely covering valve, especially anteriorly; dorsal valve strongly geniculate, no series of trails; ventral muscle fields strongly differentiated; dorsal interior thickened marginally. *Lower Carboniferous (upper Viséan)–Upper Carboniferous (lower Bashkirian):* North America, Asia, Australia.——FIG. 311,*1a–g.* **I. inflata* (MCCHESNEY), upper Viséan, Oklahoma; *a–c,* complete shell viewed ventrally, dorsally, laterally, ×1 (Gordon, Henry, & Treworgy, 1993); *d,* ventral valve exterior viewed posteriorly, ×2 (Muir-Wood & Cooper, 1960); *e,* ventral valve interior, ×1.5; *f,* dorsal valve interior, ×1.5; *g,* median section of shell showing corpus cavity, ×1 (Gordon, Henry, & Treworgy, 1993).

Sajakella NASIKANOVA in SARYTCHEVA, 1968, p. 141 [**S. formosa;* OD]. Small to medium; closely resembling *Inflatia,* but ears more prominent, ribbing commonly finer, trail spines thicker, cardinal process supported by ridges connecting to adductor scars. *Lower Carboniferous (upper Viséan)–Upper Carboniferous (Bashkirian):* Boreal Asia.——FIG. 311,*2a–d.* **S. formosa,* Bashkirian, Keregetassk Series, Kazakhstan; *a,* holotype, ventral valve exterior viewed anteriorly, PIN 1506/88, ×1; *b,* ventral valve viewed laterally, ×1; *c,* ventral valve internal cast, ×1; *d,* incomplete dorsal valve interior, ×1 (Sarytcheva, 1968).——FIG. 311,*2e. S. dzhinsetu-*

ensis LAZAREV, upper Viséan, Gobi Altai, Mongolia; ventral valve exterior, ×1 (Lazarev & Suur'suren, 1992).

Tenaspinus BRUNTON & MUNDY, 1994, p. 120 [**T. smarti;* OD]. Small, rounded elliptical outline with well-differentiated ears; ribbing starts close to umbos, widens anteriorly, disks reticulate; clasping spines at hinge, anterior ear margins, sparsely scattered on ventral disk. *Lower Carboniferous (upper Viséan):* British Isles.——FIG. 310,*2a–d. *T. smarti; a,b,* holotype, corpus plus part of one ear viewed ventrally, dorsally, Asbian, Yorkshire, BMNH BD 9544, ×2; *c,* lateral view of a shell with part of ventral valve missing to show corpus depth (*arrow*), Derbyshire, ×2; *d,* ventral view of shell clasping crinoid columnal (*arrow*), Derbyshire, ×3 (Brunton & Mundy, 1994).

Subfamily UNCERTAIN

Liolimbella LI LI in DING YUNJIE & others, 1991, p. 155[184] [**L. spanoptycha;* OD]. Resembles small *Rhytibulus,* elongate oval outline with hinge less than maximum width; rugae fine, slightly increasingly separated anteriorly toward nonrugose margin; spines at hinge and scattered from rugae on ventral valve; dorsal valve and interiors unknown. *Lower Permian:* China.——FIG. 312*a. *L. spanoptycha,* Lower Permian, Quinling; ventral valve, ×3 (Ding & others, 1991).——FIG. 312*b. L. polyptycha;* ventral valve, ×3 (Ding & others, 1991).

Family PRODUCTIDAE Gray, 1840

[Productidae GRAY, 1840, p. 151]

Deep corpus cavity; spine row(s) near hinge; teeth only in oldest genera. *Upper Devonian (Famennian)–Upper Permian (Tatarian).*

Subfamily PRODUCTINAE Gray, 1840

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 928, *ex* Productidae GRAY, 1840, p. 151, *partim*]

Small to medium size; profile geniculate with trails long, may have bordering structures; ribbing entire, reticulate posteriorly; spines commonly only on ventral valve; marginal structures well developed, including ear baffles. *Lower Carboniferous (lower Viséan)–Lower Permian.*

Tribe PRODUCTINI Gray, 1840

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 928, *ex* Productidae GRAY, 1840, p. 151, *partim*]

Ribbing relatively fine; spines thin, numerous on ears; diaphragm associated with series of dorsal trails; dorsal adductor scars may be raised on platforms. *Lower Carboniferous (Viséan)–Upper Carboniferous (Moscovian).*

FIG. 312. Productellidae (p. 467).

Productus J. SOWERBY, 1814 in 1812–1815, p. 153 [**Anomites productus* MARTIN, 1809, p. 9 (validated ICZN, 1956a, Opinion 419, p. 75); OD] [=*Producta* CONYBEARE & PHILLIPS, 1822, p. 357; *Protonia* LINK, 1830, p. 449, *non* RAFINESQUE, 1814, obj.; *Pyxis* VON CHEMNITZ, 1784, p. 301, nonbinomial); *Hubeiproductus* YANG DE-LI, 1984, p. 229[331] (type, *H. guanyinyanensis;* OD)]. Medium size; corpus deep, ventral trail long, spreading; dorsal valve geniculated, dorsal diaphragm restricted to one third anteriorly; dorsal cardinal ridges tend to diverge as lateral ridges, becoming subperipheral ridge, adductor scars slightly raised. *Carboniferous (upper Viséan–Serpukhovian, ?Bashkirian):* Eurasia, northern Africa, southern China, ?North America.——FIG. 313,*1a–e. *P. productus* (MARTIN), upper Viséan, Derbyshire; *a–d,* complete holotype, ventral, lateral views, BMNH B 40952, dorsal, posterior views of detached corpus region, ×1; *e,* anterior view of ventral valve, ×1 (new).——FIG. 313,*1f. P. carbonarius* (DE KONINCK), lower Serpukhovian, Yorkshire; latex replica of dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Carlinia GORDON, 1971, p. 258 [**Productus phillipsi* NORWOOD & PRATTEN, 1855a, p. 8; OD]. Resembles *Diaphragmus,* but short trails, lacks strong reticulation posteriorly, ribbing commonly coarse; spines on ears, lacking clumps on flanks; wide zone of diaphragms. *Lower Carboniferous (lower Serpukhovian):* North America.——FIG. 313,*3a–e. *C. phillipsi* (NORWOOD & PRATTEN), upper Chesterian, Utah; *a,b,* ventral, lateral views of specimen, ×1; *c,* dorsal view of shell, ×1; *d,* posterior view of ventral valve, ×1.5; *e,* dorsal valve interior, ×1 (Gordon, 1971).

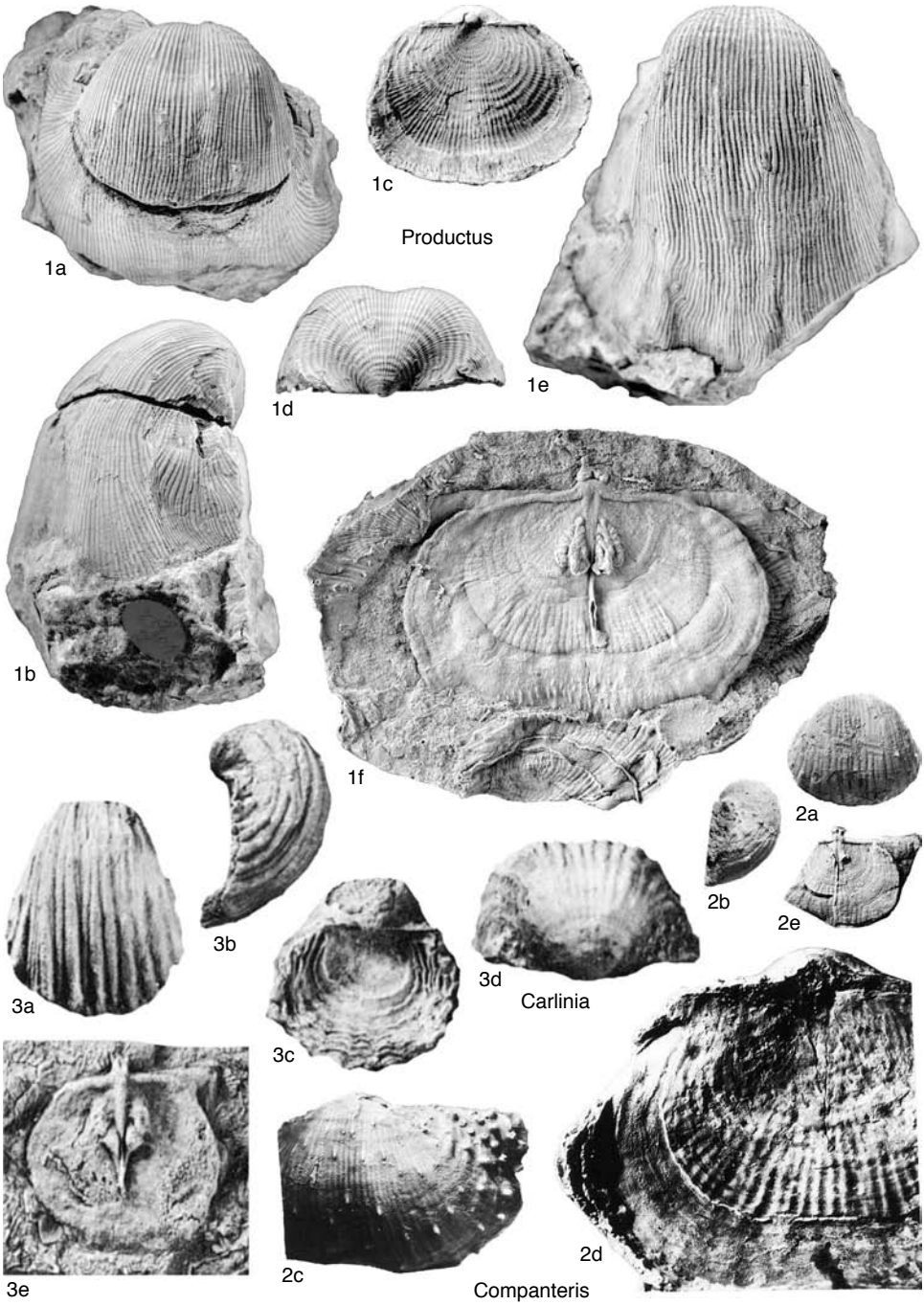

FIG. 313. Productidae (p. 467–469).

Companteris LAZAREV, 1981, p. 79 [**C. aljutovensis;* OD]. Small size; dorsal diaphragm with two trails; dorsal adductor scar platforms overhang laterally. *Upper Carboniferous (upper Bashkirian–lower Moscovian):* eastern Europe.——FIG. 313,*2a–e. *C. aljutovensis,* upper Bashkirian–lower Moscovian, Moscow Basin; *a,b,* ventral, lateral views of ventral valve, ×1; *c,* ventral valve exterior with cardinal extremity, spine bases preserved, ×2; *d,* dorsal valve exterior showing the ornament, microornament of diaphragm with traces of fragmented trails, ×5; *e,* dorsal valve interior, ×1 (Lazarev, 1981).

Diaphragmus GIRTY, 1910, p. 217 [**Productus elegans* NORWOOD & PRATTEN, 1855a, p. 13, *non* M'COY, 1884; OD; =*Productus cestriensis* WORTHEN, 1860, p. 570]. Resembles *Productus,* but with series of dorsal diaphragms, trails leaving short flat external dorsal disk. *Lower Carboniferous (upper Viséan–lower Serpukhovian):* North America.——FIG. 314,*1a–f. *P. elegans* (NORWOOD & PRATTEN), upper Viséan–lower Serpukhovian; *a,* ventral view of ventral valve, Oklahoma, ×1; *b,c,* dorsal, lateral views of complete specimen, Oklahoma, ×1; *d,* spine bases on flank, Oklahoma, ×2; *e,* longitudinal section of specimen showing two diaphragms, two successive dorsal trails, Oklahoma, ×2; *f,* dorsal valve interior, Illinois, ×4 (Muir-Wood & Cooper, 1960).

Dowhatania WATERHOUSE in WATERHOUSE & GUPTA, 1979, p. 127 [**Productus dowhatensis* DIENER, 1915, p. 27; OD] [=*Parabuxtonia* YANG & ZHANG, 1982, p. 304 (type, *P. kongjingensis;* OD); *Shishapangmaella* YANG in YANG & FAN, 1983, p. 273 (type, *S. shishapangaensis;* OD); obj.]. Poorly known; medium size; numerous fine spines, especially on ventral ears, flanks, absent dorsally; possibly with dorsal diaphragms; cardinal ridges. *?Lower Carboniferous (Viséan), Upper Carbonferous (Moscovian):* Himalayas, ?China.——FIG. 314,*2a–c. *D. dowhatensis* (DIENER), ?Bashkirian, Kashmir; *a,* ventral valve exterior with fringing spines, ×1; *b,* ventral valve exterior, ×1; *c,* incomplete dorsal valve interior, ×1 (Diener, 1915).

Lopasnia ILKHOVSKY in LAZAREV, 1990, p. 103 [**Thomasina(?) adhaerescens* IVANOVA in IVANOV, 1935, p. 112; OD]. Small to medium size; outline rather transverse; ribbing strong, coarse anteriorly; two dorsal trails, short diaphragm; cardinal process supported by adductor ridges. *Upper Carboniferous (Moscovian):* Russia.——FIG. 314,*3a,b. *L. adhaerescens* (IVANOVA), Moscovian, Moscow basin; *a,* ventral view of ventral valve, ×2 (Ivanov, 1935); *b,* exfoliated dorsal valve exterior showing adductor ridges, ×3 (new).

?Marginirugus SUTTON, 1938, p. 559 [**Productus magnus* MEEK & WORTHEN, 1862, p. 142; OD]. Large; weakly plano- to concavoconvex lateral profile with short trails, moderate to deep corpus; fine ribbing entire, rugae posterolaterally, no reticulation; spines only ventrally, thick row close to hinge, posteriorly directed, fine spines sparse on corpus; cardinal process trifid, lateral ridges continue as weak subperipheral rim. *Lower Carboniferous (lower Viséan):* central North America.——FIG. 315*a–f. **M. magnus* (MEEK & WORTHEN), lower Viséan; *a,b,* posterior, lateral views of ventral valve, Illinois, ×1; *c,* posterior view of dorsal valve showing cardinal process, Illinois, ×1; *d,* posteroventral view of ventral valve interior, Illinois, ×1; *e,f,* dorsal valve interior, ventral view of ventral valve, Oklahoma, ×1 (Muir-Wood & Cooper, 1960).

Tribe KOZLOWSKIINI Brunton, Lazarev, & Grant, 1995

[Kozlowskiini BRUNTON, LAZAREV, & GRANT, 1995, p. 928]

Spines variable, but may include few thick halteroid spines; zygidium may be present; marginal ridges associated with series of many dorsal trails. *Lower Carboniferous (Viséan)–Lower Permian (Sakmarian).*

Kozlowskia FREDERICKS, 1933, p. 29 [**Productus capaci* D'ORBIGNY, 1842, p. 50; OD]. Small, outline transverse with well-developed ears forming widest part of shell; planoconvex corpus, commonly with reticulate disks; ribbing may disappear anteriorly; spines variable from few, thick, and symmetrically arranged to more numerous scattered spines; zygidium present; endospines in single row at anterior margin of disk. *Upper Carboniferous (Bashkirian)–Lower Permian (Sakmarian):* cosmopolitan.——FIG. 316,*2a–c. **K. capaci* (D'ORBIGNY), Lower Permian, Capinota, Bolivia; *a,b,* ventral valve posteriorly, laterally, ×2; *c,* ventral valve interior, ×2 (Muir-Wood & Cooper, 1960).——FIG. 316,*2d–f. *K. splendens* (NORWOOD & PRATTEN), Upper Carboniferous, Magdalena Formation, New Mexico; *d,* dorsal view, ×1; *e,* anteroventral view, ×2; *f,* dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Eomarginifera MUIR-WOOD, 1930, p. 103 [**Productus longispinus* J. SOWERBY, 1814 in 1812–1815, p. 154; OD] [=*Lissomarginifera* LANE, 1962, p. 901 (type, *L. nuda;* OD)]. Small, around 15 mm wide; ears small, zygidium absent; six symmetrical, stout spines; commonly weak median sulcus; dorsal submarginal ridges weak anteriorly, absent ventrally. *Lower Carboniferous (Viséan–lower Serpukhovian), ?Upper Carboniferous (?lower Moscovian):* Eurasia, northern Africa, ?North America.——FIG. 316,*3a–d. **E. longispina* (J. SOWERBY), upper Viséan, Ayrshire, Scotland; ventral, dorsal, lateral, posterior views of complete specimen, ×2 (new).——FIG. 316,*3e,f. E. lobata* (J. SOWERBY); *e,* internal mold of ventral valve, Pendleian, Northumberland, British Isles, ×2; *f,* dorsal valve interior, Brigantian, ×2 (new).

Minispina WATERHOUSE, 1982a, p. 45 [**M. alata;* OD]. Similar to *Kozlowskia,* possibly differing by

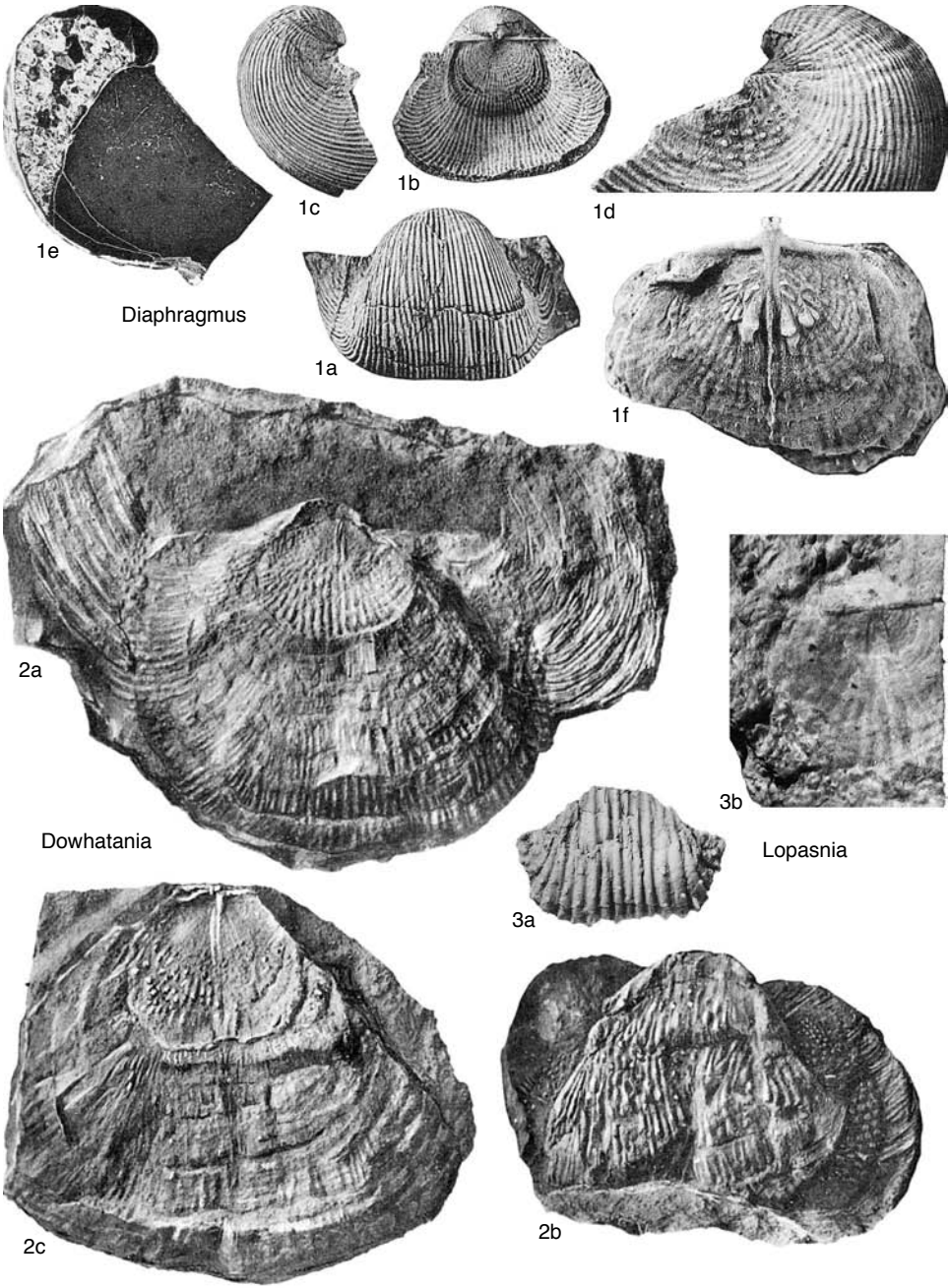

FIG. 314. Productidae (p. 469).

having no dorsal trails. *Upper Carboniferous (Kasimovian–Gzhelian):* southeastern Asia.——FIG. 316,*1a–c.* **M. alata,* upper Upper Carboniferous, northeastern Thailand; *a,* ventral valve exterior, ×2.2; *b,* ventral valve internal mold, ×3.5; *c,* dorsal valve internal mold, ×3 (Waterhouse, 1982a).

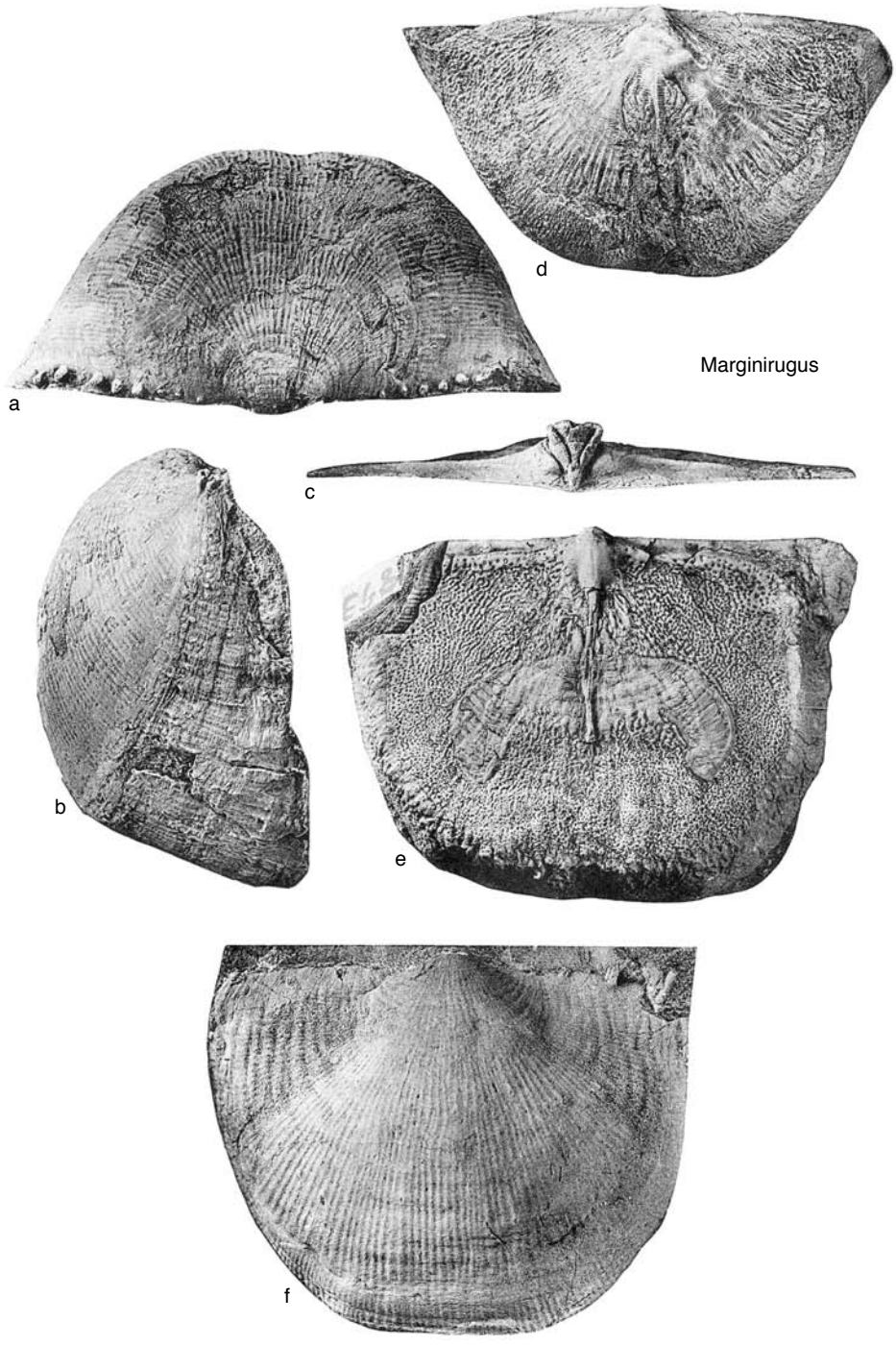

FIG. 315. Productidae (p. 469).

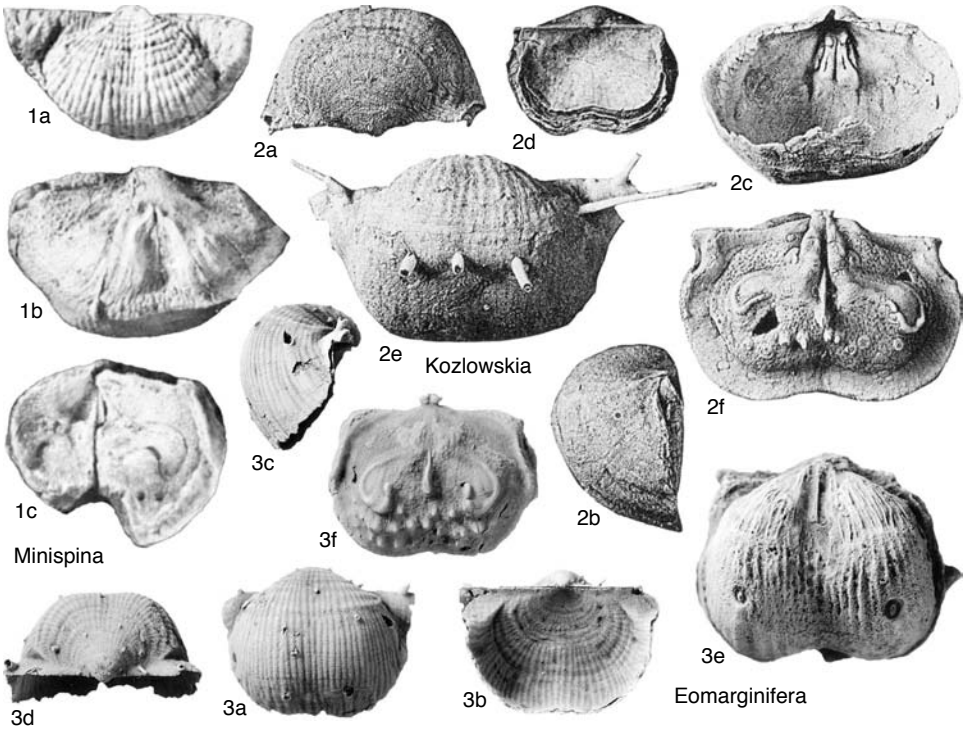

FIG. 316. Productidae (p. 469–470).

Tribe RETARIINI
Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 928, *ex* Retariinae MUIR-WOOD & COOPER, 1960, p. 230]

Trail nonlamellose, may be tubiform; row of thick spines at base of ventral flank, sparse or absent from dorsal valves; dorsal adductor scars commonly positioned relatively anteriorly, with pitted, tuberculate surface ornamentation in ventral umbo. *Lower Carboniferous (lower Viséan)–Lower Permian.*

Kutorginella IVANOVA, 1951, p. 329 [**K. mosquensis;* OD] [=*Retaria* MUIR-WOOD & COOPER, 1960, p. 230 (type, *R. umbonata;* OD); *Neoproboscidella* IVANOVA, 1949, *nom. nud.; Calliomarginatia* CHING in ZHANG & CHING, 1976, p. 181 (type, *C. himalayensis;* OD); *Aspinosella* WATERHOUSE, 1982a, p. 47 (type, *Kutorginella uddeni* COOPER & GRANT, 1975, p. 1029; OD)]. Ventral median sulcus prominent, may form extended (nasute) trail medianly; ears large, almost flat; cardinal or lateral ridges continuous with ear baffles, extending as endospinous marginal ridge. [A *Retaria* group of species with widely divergent lateral ridges, poorly differentiated from ear baffles, may be separable from the *mosquensis* group of species with cardinal or lateral ridges close to the hinge line]. *Upper Carboniferous (Kasimovian)–Lower Permian:* eastern Europe, middle Asia, North America, China.——FIG. 317,*1a–d. *K. mosquensis,* Kasimovian–Gzhelian, Moscow Basin; *a,* anterior view of specimen lacking nasute trail, ×1; *b,* ventroanterior view of specimen showing nasute trail, ×1 (Muir-Wood & Cooper, 1960); *c,* posterior view of ventral valve, ×1.2; *d,* dorsal valve interior, ×1.5 (Sarytcheva, 1971).——FIG. 317,*1e,f. K. umbonata* (MUIR-WOOD & COOPER), Leonardian, Texas; *e,* lateral view of shell, ×1; *f,* dorsal valve interior, ×1.5 (Muir-Wood & Cooper, 1960).

Antiquatonia MILORADOVICH, 1945, p. 496 [**Productus antiquatus* J. SOWERBY, 1821 in 1821–1822, p. 15; OD]. Ventral spine ridge flanking ears with internal complimentary lateral ridges; ventral spines thick, halteroid. *Carboniferous (Viséan–Serpukhovian):* cosmopolitan.——FIG. 317,*2a,b. *A. antiquata* (J. SOWERBY), Viséan, Derbyshire; lectotype selected by MUIR-WOOD, 1928, anterior, lateral views of specimen lacking ears, BMNH B 60956, ×1 (new).——FIG. 317,*2c–f. A. hindi* (MUIR-WOOD), lower Brigantian, Derbyshire; *c,d,* holotype, posterior, lateral views, BMNH B 47860, ×1 (Muir-Wood, 1928); *e,f,* posterior view, showing part of internal mold, oblique lateral view of ventral valve, ×1 (new).

Kelamelia ZHANG ZI-XIN in ZHANG & others, 1983, p. 305 [**K. typica;* OD]. Poorly known; ventral spines

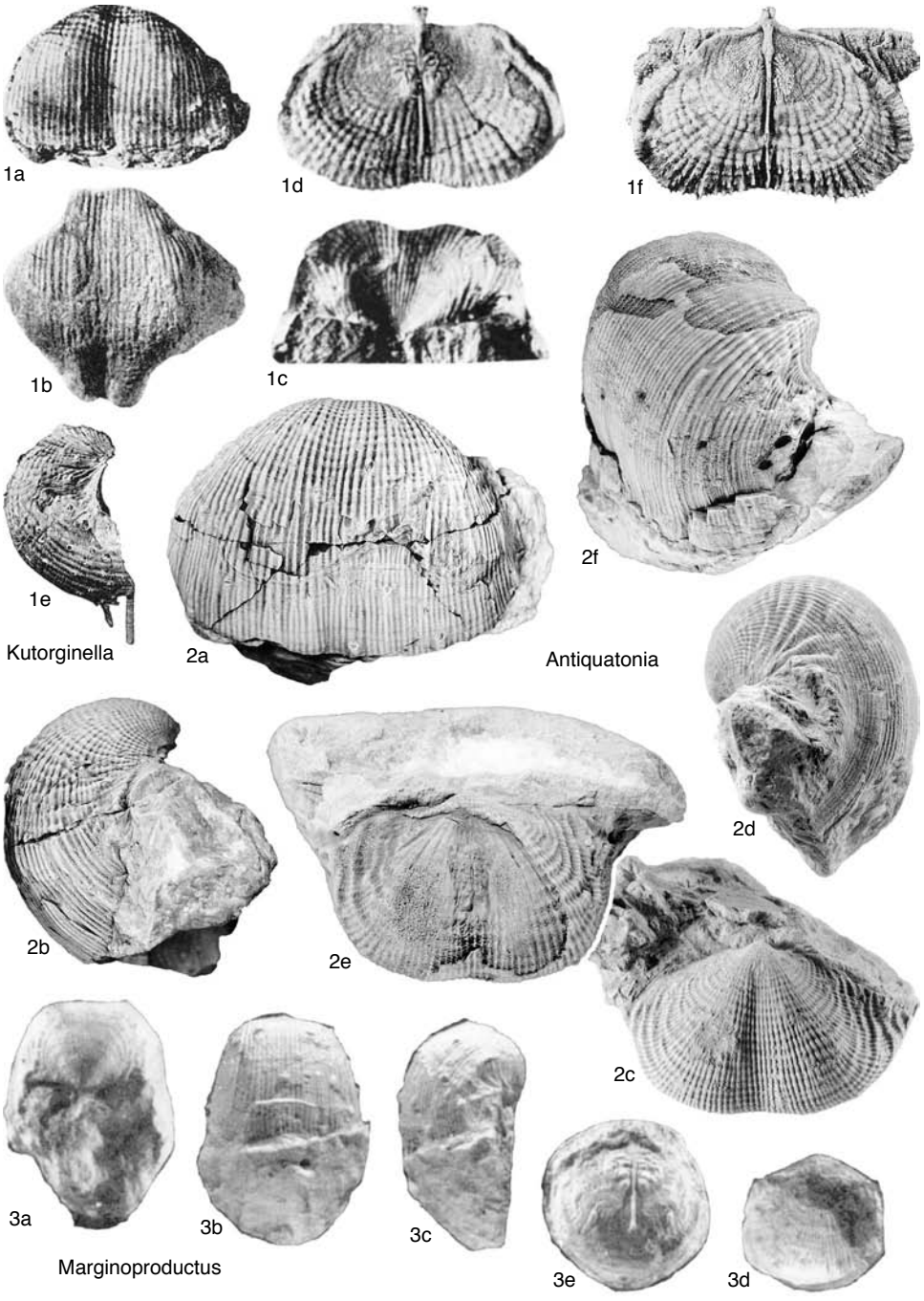

FIG. 317. Productidae (p. 472–475).

at hinge, flank to ear junction; lateral ridges ?short, slightly divergent, not extended as ear baffles. *Upper Carboniferous (Moscovian):* northern China.

——FIG. 318,*1a–d. *K. typica,* Moscovian, Xinjiang; anterior, dorsal, lateral, posterior views of complete specimen, ×1 (Zhang & others, 1983).

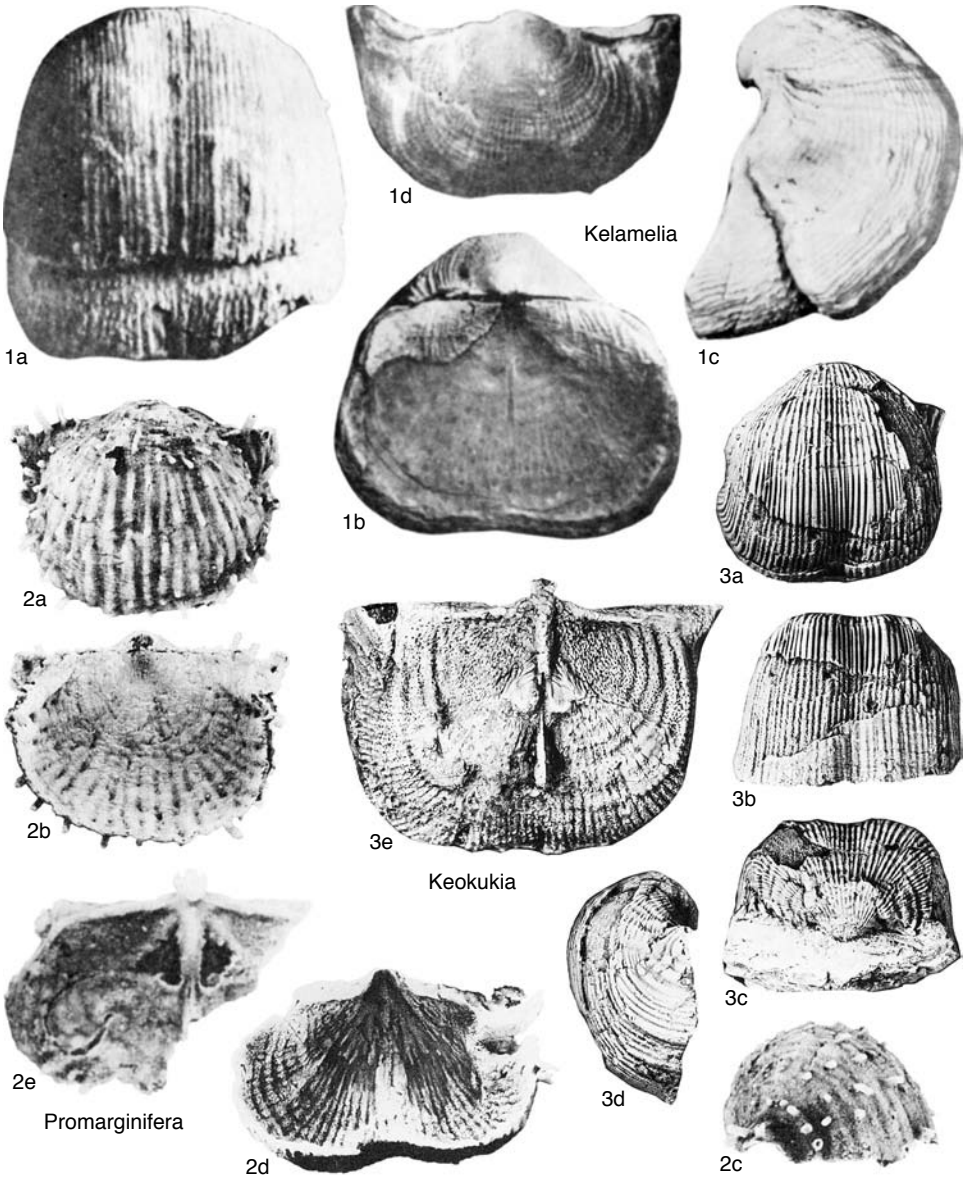

FIG. 318. Productidae (p. 472–475).

Keokukia CARTER, 1990, p. 229 [**K. sulcata;* OD]. Medium size; ears small, pointed; spine row diverges slightly from ventral hinge, others on flanks, trail, no dorsal spines; lateral ridges close to hinge, no marginal ridges. *Lower Carboniferous (lower Viséan):* central North America.——FIG. 318,*3a–e.* **K. sulcata,* lower Viséan, Illinois; *a–d,* holotype, ventral, anterior, posterior, lateral views, CMNH 34891, ×1; *e,* dorsal valve interior, ×1.5 (Carter, 1990).

Marginoproductus TAN ZHEN-XIU, 1986, p. 435[443] [**M. hunanensis;* OD]. Small to medium sized, around 20 mm wide; deep corpus with long trail; dorsal spines reportedly absent, but if present should be assigned to the Tolmatchoffiinae; closely resembles *Marginatia. Lower Carboniferous (lower*

Viséan): southern China.——Fig. 317,*3a–e. *M. hunanensis,* lower Viséan, Hunan; *a,* holotype, posterior view, HB 318, ×1; *b,c,* anterior, lateral views of ventral valve, ×1; *d,* dorsal valve exterior, ×1; *e,* dorsal valve interior, ×1 (Tan, 1986).

Promarginifera Shiells, 1966, p. 428 [**P. trearnensis;* OD]. Small; corpus deep, ears well differentiated, trail simple; spines numerous, covering ventral valve, few and fine dorsally; lateral ridges close to hinge. *Lower Carboniferous (upper Viséan):* British Isles.——Fig. 318,*2a–e. *P. trearnensis,* Asbian, Ayrshire; *a–c,* holotype, ventral, dorsal, lateral views, HM L6202, ×2; *d,* ventral valve interior, ×2; *e,* dorsal valve interior, ×2.5 (Shiells, 1966).

Svalbardoproductus Ustritsky, 1962b, p. 82 [**S. stratoauritus;* OD]. Similar to *Thamnosia,* but said to differ by lacking spine clusters on ears; ribbing weak, indistinct anteriorly. *upper Lower Permian (Kungurian):* Spitzbergen.

Tesuquea Sutherland & Harlow, 1973, p. 53 [**T. formosa;* OD]. Small to medium size; corpus deep; spines only ventrally, small over reticulate disk, single or double rows prominent on flanks, continued onto trail; cardinal process small, sessile, cardinal ridges angle sharply at ears, continue as ear baffles. *lower Upper Carboniferous (Bashkirian):* southern North America.——Fig. 319,*2a–e. *T. formosa,* Bashkirian, New Mexico; *a,* holotype, ventral view, OU 7659, ×1; *b,c,* posterior, lateral views, ×2; *d,* dorsal valve exterior, ×2; *e,* dorsal valve interior, ×2 (Sutherland & Harlow, 1973).

Thamnosia Cooper & Grant, 1969, p. 10 [**T. anterospinosa;* OD] [=?*Neopugilis* Li in Ding & others, 1991, p. 159[186] (type, *N. typicus;* OD); *Thuleproductus* Sarytcheva & Waterhouse, 1972, p. 67 (type, *T. crassauritus;* OD)]. Medium, widest at hinge; ventral disk gently convex, geniculate with long trail, medianly sulcate; spines on both valves, ventral valve with clusters of thicker spines on lateral slopes and anterior trail, dorsal spines small, thin; ear baffles in both valves, dorsally as extensions of cardinal ridges that diverge from hinge; marginal ridge becoming overgrown by row of endospines anteriorly. [The inclusion of *Neopugilis* from the Lower Permian of Shaanxi, China, may extend the range from the uppermost Carboniferous; interiors are poorly known.] *?upper Upper Carboniferous (?Gzhelian), upper Lower Permian (Roadian):* USA, Arctic Canada, eastern Greenland, Arctic Eurasia, ?China.——Fig. 319,*1a–e. *T. anterospinosa,* Lower Permian, Cathedral Mountain Formation, Texas; *a–c,* holotype, viewed ventrally, dorsally, laterally, USNM 149852, ×1; *d,* ventral valve interior, ×1; *e,* dorsal valve interior, ×1 (Cooper & Grant, 1975).

Tubaria Muir-Wood & Cooper, 1960, p. 236 [**Productus genuinus* Kutorga, 1844, p. 93; OD]. Resembles *Kutorginella,* but with larger convex ears and greatly extended anterior margin, forming tube; dorsal marginal ridge smooth. *Upper Carboniferous (Moscovian)–Lower Permian (Sakmarian):* Russia, Fergana.——Fig. 319,*3a–d. *T. genuina* (Kutorga), Schwagerina Limestone, Ural Mountains; *a,* shell viewed ventrally, ventral valve missing over right ear, ×1; *b,c,* shell viewed laterally, ventrally with ventral corpus removed, showing dorsal external mold, ×1 (Muir-Wood & Cooper, 1960); *d,* dorsal valve interior, ×1.5 (Sarytcheva, 1971).

Tribe SPYRIDIOPHORINI Muir-Wood & Cooper, 1960

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 928, *ex* Spyridiophoridae Muir-Wood & Cooper, 1960, p. 230]

Ribbing coarse, homogeneous anteriorly; spine row on each arched ear; no diaphragm or series of dorsal trails; dorsal adductor platforms well developed (spyridium). *Upper Carboniferous (Moscovian)–Lower Permian (Sakmarian, ?Artinskian).*

Spyridiophora Cooper & Stehli, 1955, p. 471 [**S. distincta;* OD] [=*Spiridiophora* Sarytcheva in Sarytcheva, Licharew, & Sokolskaja, 1960, p. 234]. Medium size with transverse outline, ears large; ventral sulcus originating on umbo; dorsal disk almost flat, geniculate; spines include ear clusters, none dorsally; ear baffles in both valves strong; cardinal process sessile, bilobed, quadrifid; dorsal adductor scars raised, laterally directed platforms or true spyridium. *Lower Permian (Asselian–Sakmarian, ?Artinskian):* USA, southeastern Asia.——Fig. 320,*2a–e. *S. distincta,* Lower Permian, Wolfcamp Formation, Texas; *a–c,* shell viewed ventrally, anteriorly, dorsally, ×1; *d,* dorsal valve viewed posteriorly showing spyridium, ×3 (Muir-Wood & Cooper, 1960); *e,* holotype, dorsal valve interior, USNM 124117, ×2 (Cooper & Grant, 1975).

Alexenia Ivanova in Ivanov, 1935, p. 89 [**A. reticulata;* OD]. Externally similar to *Spyridiophora* but internal dorsal adductor platforms separated medianly, and less elevated. *Upper Carboniferous (Moscovian–Kasimovian):* Eurasia.——Fig. 320,*1a–c. *A. reticulata,* Moscow basin; *a,* ventral valve exterior, Moscovian, ×2; *b,* ventral valve exterior, Moscovian, ×1 (Ivanova, 1935); *c,* dorsal valve interior, Kasimovian, ×1 (Lazarev, 1990).

Subfamily LEIOPRODUCTINAE Muir-Wood & Cooper, 1960

[Leioproductinae Muir-Wood & Cooper, 1960, p. 168]

Ribbing commonly absent or weak, never at beak; dorsal spines commonly absent; teeth absent in all but oldest genera. *Upper Devonian (Famennian)–Upper Permian (Capitanian).*

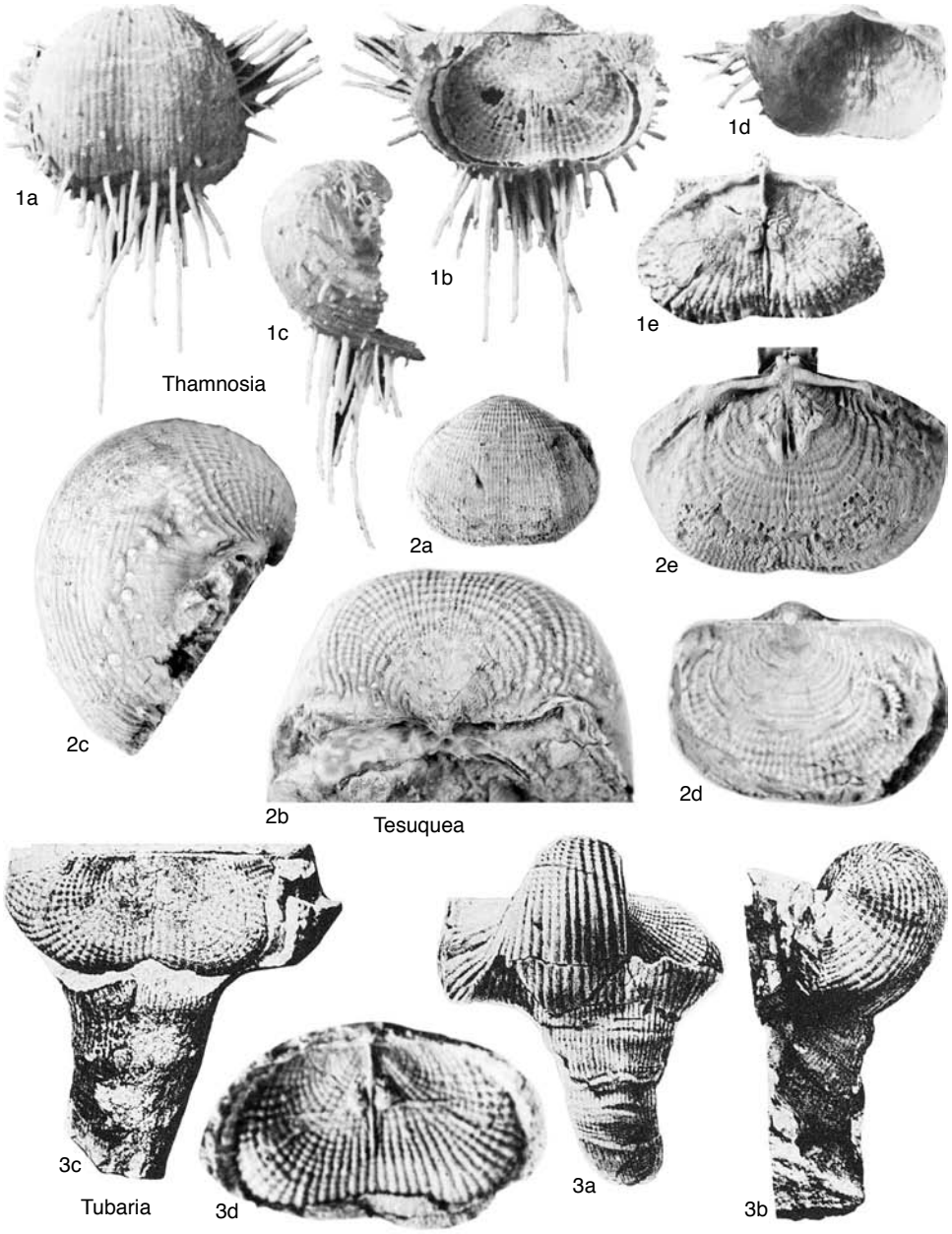

FIG. 319. Productidae (p. 475).

Tribe LEIOPRODUCTINI Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, herein, *ex* Leioproductinae MUIR-WOOD & COOPER, 1960, p. 168]

Small to medium sized; ribbing absent, but commonly with ventral median weak fold; ventral spines sparse, dorsal spines absent; teeth in early genera. *Upper Devonian (Famennian)–Lower Carboniferous (lower Viséan).*

Leioproductus STAINBROOK, 1947, p. 307 [**Productella coloradoensis* var. *plicatus* KINDLE, 1909, p. 18; OD].

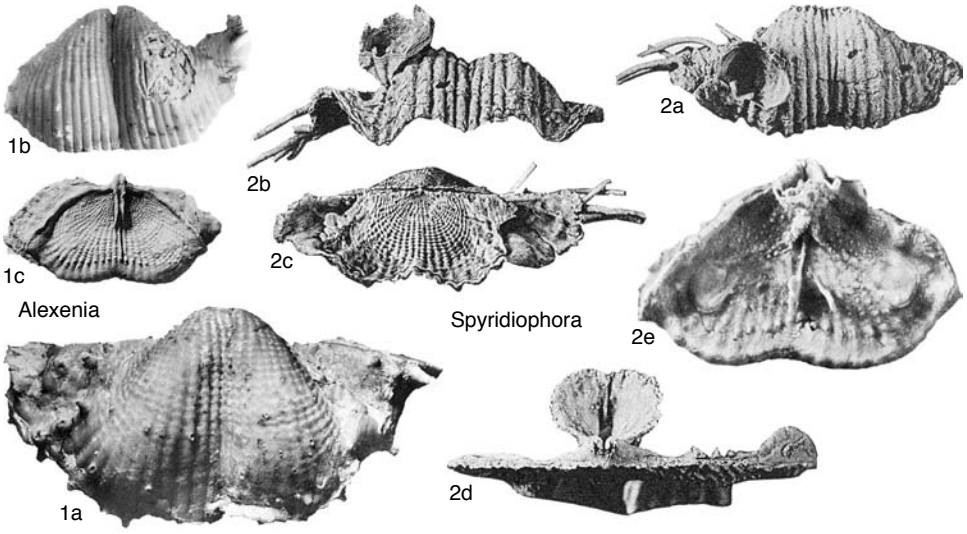

FIG. 320. Productidae (p. 475).

Spines sparse, evenly distributed roughly radially, commonly including ventral median row on low ridge; weak lateral ridges extend toward lateral margins, short accessory ridges posterior to adductor scars; cardinal process pit. *Upper Devonian (upper Famennian):* North America, Asia.——FIG. 321,*1a–f. *L. plicatus* (KINDLE), uppermost Famennian, New Mexico; *a,* posterior view, ×1; *b,* anteroventral view, ×2; *c,* dorsal view, ×1; *d,* lateral view, ×2; *e,* dorsal valve interior, ×2; *f,* conjoined valves showing dorsal, ventral interiors, ×2 (Muir-Wood & Cooper, 1960).

Ardiviscus LAZAREV in LAZAREV & PUSHKIN, 1986, p. 42[35] [**A. naidovense* PUSHKIN in LAZAREV & PUSHKIN, 1986, p. 43[38]; OD]. Similar to *Leioproductus,* but with thinner spines, occurring more densely posterolaterally; teeth present, but no cardinal process pit. *Upper Devonian (lower Famennian):* Eurasia, ?North America.——FIG. 321,*5a–e. *A. naidovense* PUSHKIN, lower Famennian, Belorussia, Gomel' region; *a,b,* holotype, ventral, lateral views, PIN N 4067/113, ×1; *c,* oblique lateral view of ventral valve exterior, ×1; *d,* dorsal view of shell, ×1; *e,* partial ventral valve internal mold showing muscle scars, ×3 (Lazarev & Pushkin, 1986).

Bispinoproductus STAINBROOK, 1947, p. 311 [**B. varispinosus;* OD]. Resembles *Leioproductus,* but with numerous ventral small spines, anteriorly on elongate bases, separated by slightly lamellose bands. *Upper Devonian (upper Famennian):* southern North America.——FIG. 321,*4a–d. *B. varispinosus,* Famennian, New Mexico; *a,* dorsal view of complete specimen, ×1; *b,* ventral view of ventral valve, ×1; *c,* lateral view of ventral valve, note spines, ×1; *d,* dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Galeatella MUIR-WOOD & COOPER, 1960, p. 173 [**G. galeata;* OD]. Small; relatively shallow corpus; ventral disk weakly convex, gentle median sulcus; spines thin, at hinge, on indistinct rugae and anteriorly; cardinal process pit, accessory ridges posterior to adductor scars, no cardinal ridges. *Upper Devonian (upper Famennian):* North America.——FIG. 321,*2a–e. *G. galeata,* uppermost Famennian, New Mexico; *a–c,* ventral, anterior, lateral views of ventral valve, ×1; *d,* dorsal view of nearly complete specimen, ×1; *e,* dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Grandiproductella LAZAREV in LAZAREV & SIMAKOV, 1987, p. 121[134] [**G. omolonensis* SIMAKOV in LAZAREV & SIMAKOV, 1987, p. 121[135]; OD]. Medium sized, around 30 mm wide; spines thin, in line at hinge, elsewhere rare; no ventromedian sulcus; teeth strong. *Upper Devonian (Famennian):* northeastern Asia.——FIG. 322,*1a–c. *G. omolonensis* SIMAKOV, Famennian, Omolon Massif; *a,* holotype, ventral view, PIN N 4112/101, ×1; *b,* posterior view of ventral valve, ×1; *c,* posteroventral view of exfoliated ventral valve showing muscle scars, ×1 (Lazarev & Simakov, 1987).

?Hunanoproductus HOU HONG-FEI, 1965, p. 117 [**H. hunanensis;* OD]. Smaller medium size, outline subrounded; profile geniculate with flared trail; spines at hinge and rare, thin anteriorly; posterior rugae slight, corpus relatively shallow. *Lower Carboniferous (lower Tournaisian):* southern China.——FIG. 321,*3a–d. *H. hunanensis,* lowermost Tournaisian, southern China; *a,b,* holotype, lateral, posterior views of ventral valve, IV 530, ×1; *c,d,* ventral, dorsal views of complete specimen, ×1 (Hou, 1965).

Kavesia LAZAREV in LAZAREV & SIMAKOV, 1987, p. 122[136] [**K. intrastriata* SIMAKOV in LAZAREV &

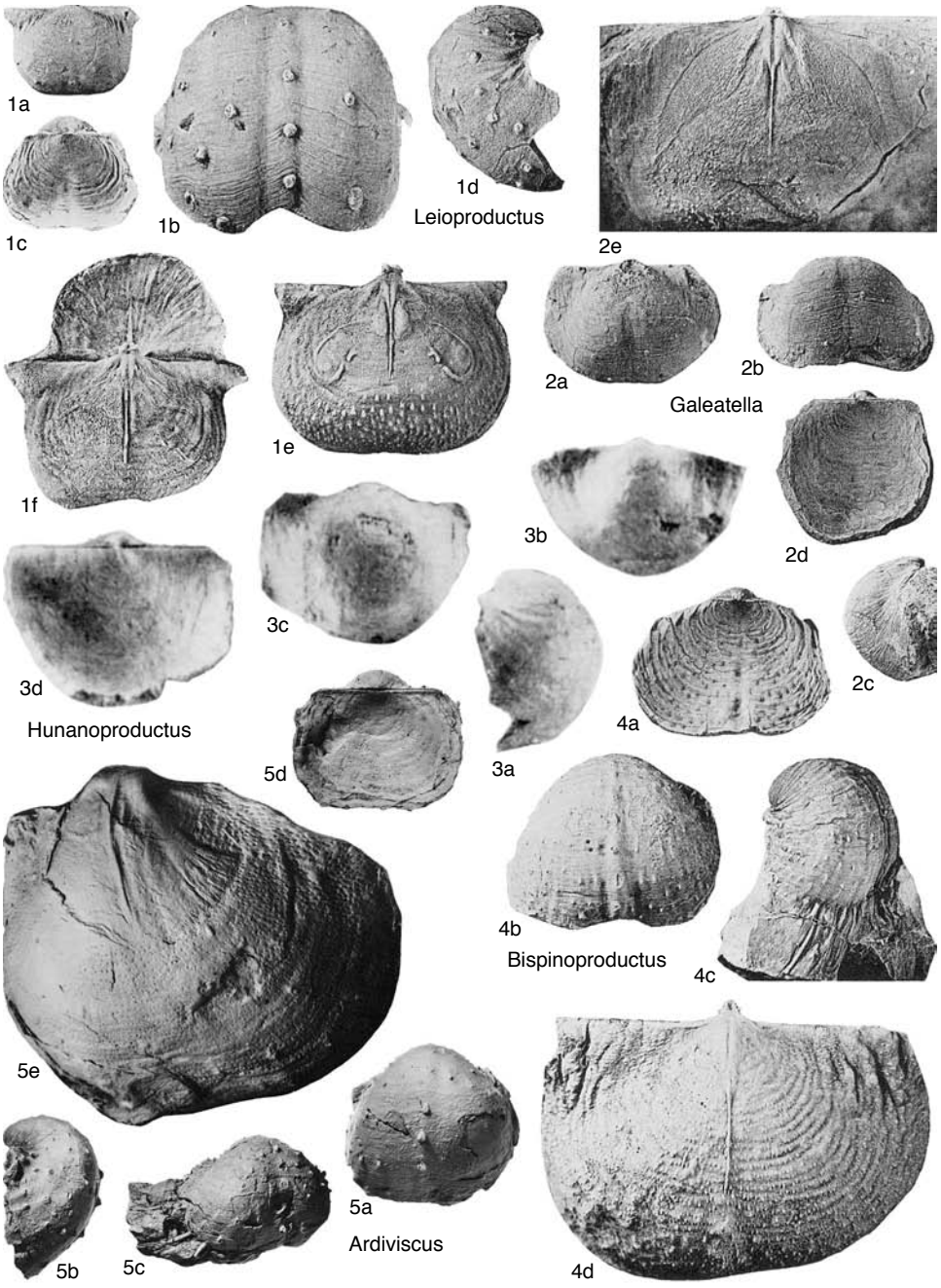

FIG. 321. Productidae (p. 476–477).

SIMAKOV, 1987, p. 123[136]; OD]. Resembles *Grandiproductella,* but dorsal visceral disk more flat; teeth absent; no cardinal process pit. *?upper Upper Devonian, Lower Carboniferous (lower Tournaisian):* northeastern Asia.——FIG. 322,*4a–d. *K. intrastriata* SIMAKOV, ?uppermost Famennian–lower Tournaisian, Omolon Massif; *a,* holotype, dorsal view, showing cardinal process, PIN N 4112/104,

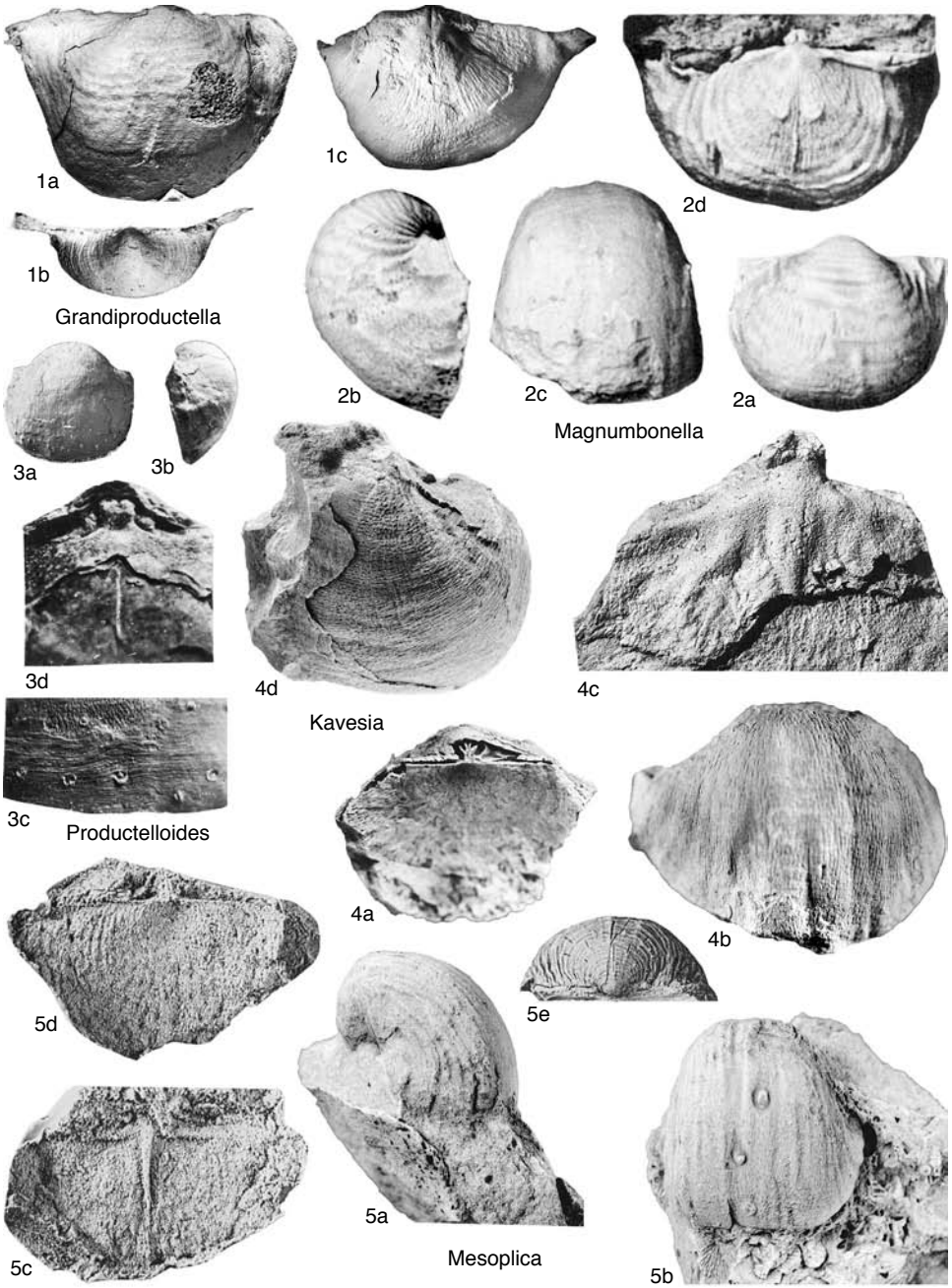

FIG. 322. Productidae (p. 477–480).

×1; *b,* internal cast of ventral valve, ×1; *c,* incomplete dorsal valve interior, ×3 (Lazarev & Simakov, 1987); *d,* anterolateral view of largely exfoliated valve, ×1 (new).

Magnumbonella CARTER, 1968, p. 1145 [**M. macrura;* OD]. Lateral profile strongly curved with deep corpus; rugae confined posteriorly, strong on flanks; spines rare, fine on dorsal valve, occasional elongate

spine bases distal to spines; no cardinal process pit; lateral ridges diverge slightly from hinge, reaching ears. *Lower Carboniferous (Tournaisian–lower Viséan):* central North America.——Fig. 322,*2a–d.* **M. macrura,* lower Viséan, Missouri; *a,b,* ventral, lateral views of ventral valve, ×1.5; *c,* anterior view of ventral valve, ×1.5; *d,* dorsal valve interior, ×2 (Carter, 1968).

Mesoplica Reed, 1943, p. 97 [**Leptaena praelonga* J. de C. Sowerby, 1840, pl. 53, fig. 29; OD]. Medium size; distinct ventral median fold bearing thicker spines in some; ribbing incipient anteriorly on corpus, trail; teeth absent; cardinal ridges short. *Upper Devonian (upper Famennian):* Europe, northern Africa, ?Asia.——Fig. 322,*5a–d.* **M. praelonga* (J. de C. Sowerby), uppermost Famennian, Devonshire; *a,b,* lateral, anterior views of ventral valve internal mold, ×1 (new); *c,d,* replicas of interior, exterior of posterior part of dorsal valve, ×2 (Muir-Wood & Cooper, 1960).——Fig. 322,*5e. M. simplicior* (Nalivkin), Famennian, Kirghizia; posterior view of ventral valve, ×1 (Muir-Wood & Cooper, 1960).

Productelloides O. Kotlyar, 1985, p. 112[97] [**P. gorobtsovensis;* OD]. Resembles *Leioproductus,* but without ventromedian fold, spines fine, widely scattered; teeth small. *Upper Devonian (upper Famennian):* Ukraine.——Fig. 322,*3a–d.* **P. gorobtsovensis,* upper Famennian, Poltava District; *a,b,* holotype, anteroventral, lateral views, IGN 2078/110, ×1; *c,* view of ventral valve surface at anterior margin, ×3; *d,* part of dorsal valve interior, ventral umbo showing teeth, ×5 (Kotlyar, 1985).

Tribe HORRIDONIINI Muir-Wood & Cooper, 1960

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 928, *ex* Horridoniinae Muir-Wood & Cooper, 1960, p. 292]

Medium or commonly large, thick-walled valves; ribs weak or absent, one to three rows of halteroid spines commonly on ventral ears and, rarely, one row near dorsal hinge; rarely other dorsal spines; marginal structures commonly absent. *Lower Carboniferous (Serpukhovian)–Upper Permian.*

Horridonia Chao, 1927b, p. 24 [**Productus horridus* J. Sowerby, 1822 in 1821–1822, p. 17; OD] [?=*Sowerbina* Fredericks, 1928, p. 778 (type, *Productus timanicus* Stuckenberg, 1905, p. 86; OD); *Pleurohorridonia* Dunbar, 1955, p. 89 (type, *P. scoresbyensis;* OD)]. Medium size, outline pentagonal with wide hinge; weak median sulcus and dorsal fold; ribbing, rugae absent; spines in one to three rows on ears, few scattered on ventral valve, single row near dorsal hinge; dorsal lateral ridges extend to ears; dorsal muscle field rhombic; endospines around anterior margins of disk. *Upper Permian:* Europe, Arctic regions, ?Pakistan (Salt Range).——Fig. 323,*1a–f.* **H. horrida* (J. Sowerby); *a–e,* shell viewed ventrally, posteriorly, anteriorly, laterally, dorsally, Zechstein, Thüringia, Germany, ×1; *f,* dorsal valve interior, Magnesian Limestone, Durham, ×1 (Muir-Wood & Cooper, 1960).

Bailliena Nelson & Johnson, 1968, p. 723 [**B. yukonensis;* OD]. Resembles *Horridonia,* but lacks dorsal spines near hinge, but with spines at dorsal geniculation zone; lamellose, especially dorsally; ribbed anteriorly on trail, anterior to thick spine bases. *Upper Carboniferous (Gzhelian)–Lower Permian (Asselian):* northern Canada.——Fig. 323,*2a–d.* **B. yukonensis,* Gzhelian–Asselian, Yukon Territory; *a,* holotype, viewed laterally, UCF 1088, ×1; *b,* holotype, close up of ventral hinge region, UCF 1088, ×2; *c,d,* ventral, dorsal views of specimen, ×1 (Nelson & Johnson, 1968).

Burovia Ustritsky, 1980, p. 25 [**B. selanderensis;* OD]. Medium to large with variable outline, ears well differentiated; median sulcus originating on disk; prominent growth lines may form bands anteriorly; spines lacking at hinge, arranged in well-spaced rows on ventral valve and row at dorsal hinge with thick cluster on ears; cardinal process sessile, quadrifid; cardinal ridges weak or absent, marginal ridges strong laterally, continued anteriorly; shell substance thick, giving strong morphology with wide adductor scars. *upper Upper Permian:* Arctic regions.——Fig. 324*a–c.* **B. selanderensis,* Selander Formation, Selander Bay, Spitzbergen; *a,* holotype, ventral valve exterior, repository and number unknown, ×1; *b,* incomplete ventral valve with spine cluster, ×1; *c,* dorsal valve interior, ×1 (Ustritsky, 1980).——Fig. 324*d. B. maynei* (Dunbar); anteroventral view of specimen, ×1 (Ustritsky, 1980).

Praehorridonia Ustritsky, 1962a, p. 57 [**P. dorsoplicata;* OD]. Shape similar to *Horridonia,* but with thin spines scattered over ventral valve and anteriorly only on dorsal valve; incipient radial ribbing; lateral ridges thick, extended to separate ears. *Carboniferous (Serpukhovian–Bashkirian):* Arctic regions, Siberia, Canada.——Fig. 325,*1a–d.* **P. dorsoplicata,* lowermost Bashkirian, Kholodinn Formation, Taymyr; *a,b,* holotype, lateral, ventral views, VSEGEI 8363/176, ×1; *c,* ventral view showing incipient ribbing, VSEGEI 8363/176, ×2; *d,* dorsal valve interior, ×1 (Ustritsky, 1962a).

?Rugoclostus Easton, 1962, p. 59 [**R. nivalis;* OD]. Similar to *Praehorridonia* but possibly differs in having ventral ginglymus and spines more densely covering dorsal ears. *lower Upper Carboniferous (lower Bashkirian):* central North America.——Fig. 325,*2a–c.* **R. nivalis,* lower Bashkirian, Cameron Creek Formation, Morrowan, Montana; holotype, dorsal, posterior, anteroventral views, USNM 118789, ×1 (Easton, 1962).

Tityrophoria Waterhouse in Bamber & Waterhouse, 1971, p. 214 [**T. nelsoni;* OD]. Resembles *Praehorridonia,* but differs in lacking crowded spines

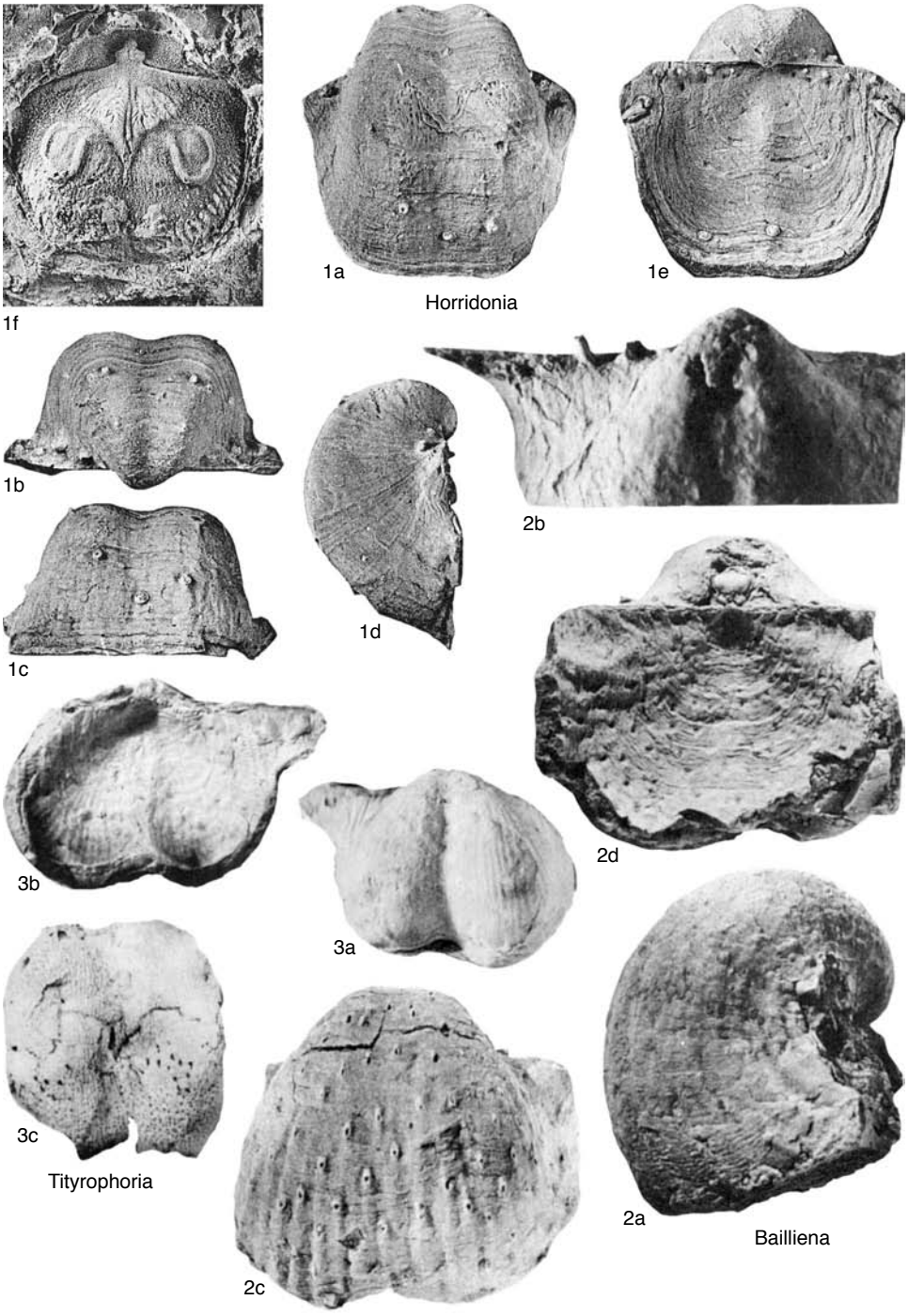

FIG. 323. Productidae (p. 480–483).

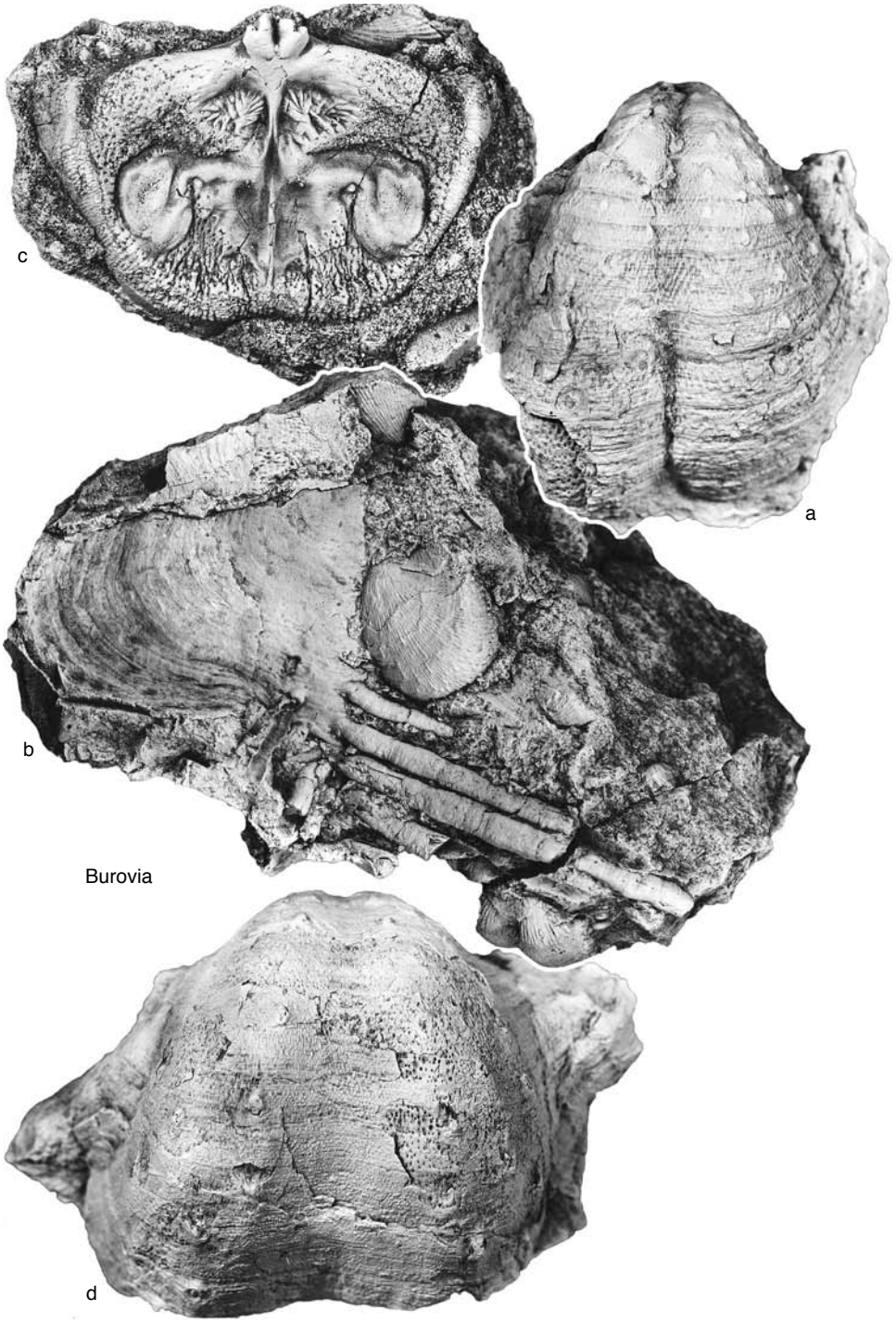

FIG. 324. Productidae (p. 480).

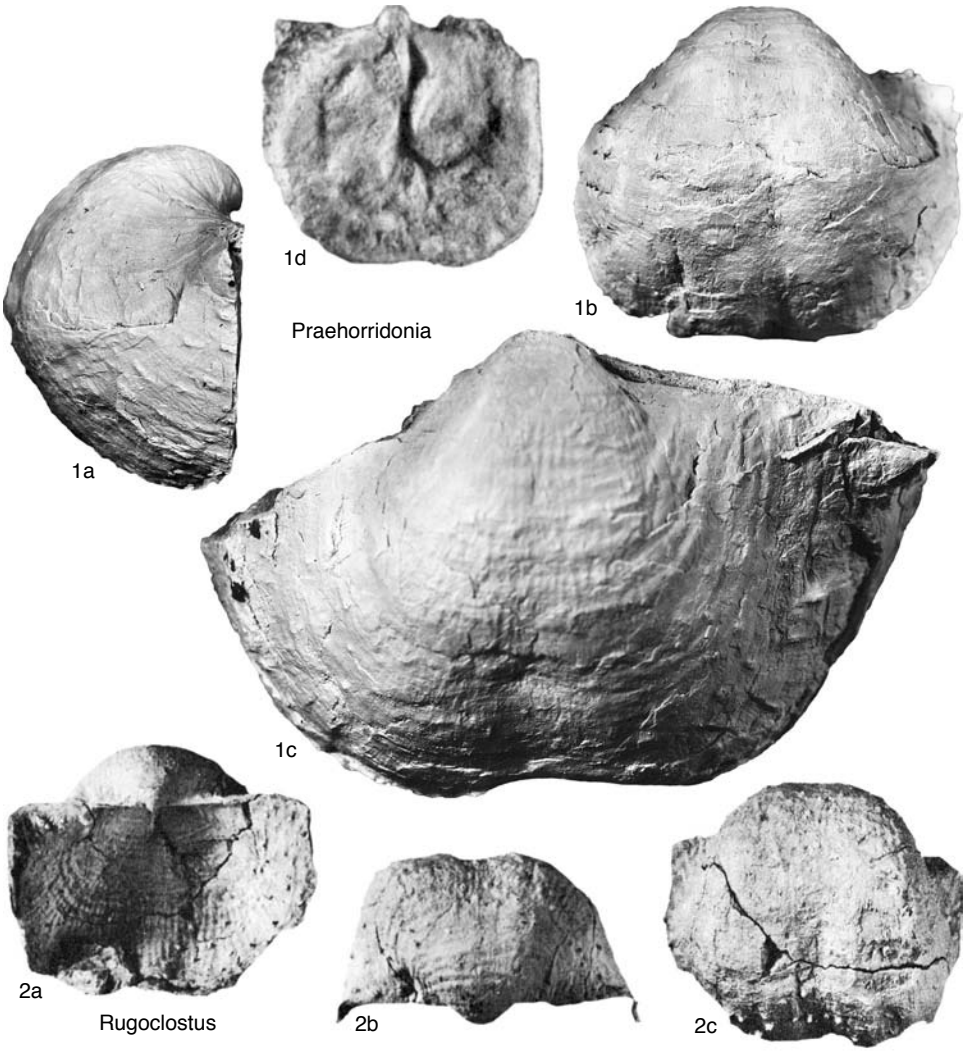

FIG. 325. Productidae (p. 480).

on ventral flange and trail, and in having only rare or absent dorsal spines. *Lower Permian:* Canada. ——FIG. 323,*3a–c.* **T. nelsoni,* Lower Permian, basal Tahkandit Formation, Yukon Territory; *a,b,* holotype, viewed ventrally, dorsally, GSC 26417, ×1; *c,* anteroventral view of internal cast, ×1 (Bamber & Waterhouse, 1971).

Tribe SEMIPRODUCTINI McKellar, 1970

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 927, *ex* Semiproductinae MCKELLAR, 1970, p. 26] [=Lomatiphorinae ROBERTS, 1971, p. 84]

Medium size with deep corpus cavity, long trails; elongate spine bases arranged quincuncially on ventral disk, spines extending onto trail; ribs originate anteriorly on disks and always occur on trails; lateral ridges commonly short, no marginal structures; teeth in early genera. *Upper Devonian (Famennian)–Lower Carboniferous (lower Viséan).*

Semiproductus BUBLICHENKO, 1956, p. 99 [**S. minax;* OD]. Size medium, around 35 mm; outline subquadrate to elongate with broad sulcus anteriorly, ventral profile strongly convex; rugae weak or incomplete on disks with elongate spine bases; spines on weak ribs on ventral trail; lateral ridges prominent, but short. *upper Upper Devonian (upper Famennian)–lower Carboniferous (lower Tournaisian):* Ural Mountains, Asia, northern Australia.——

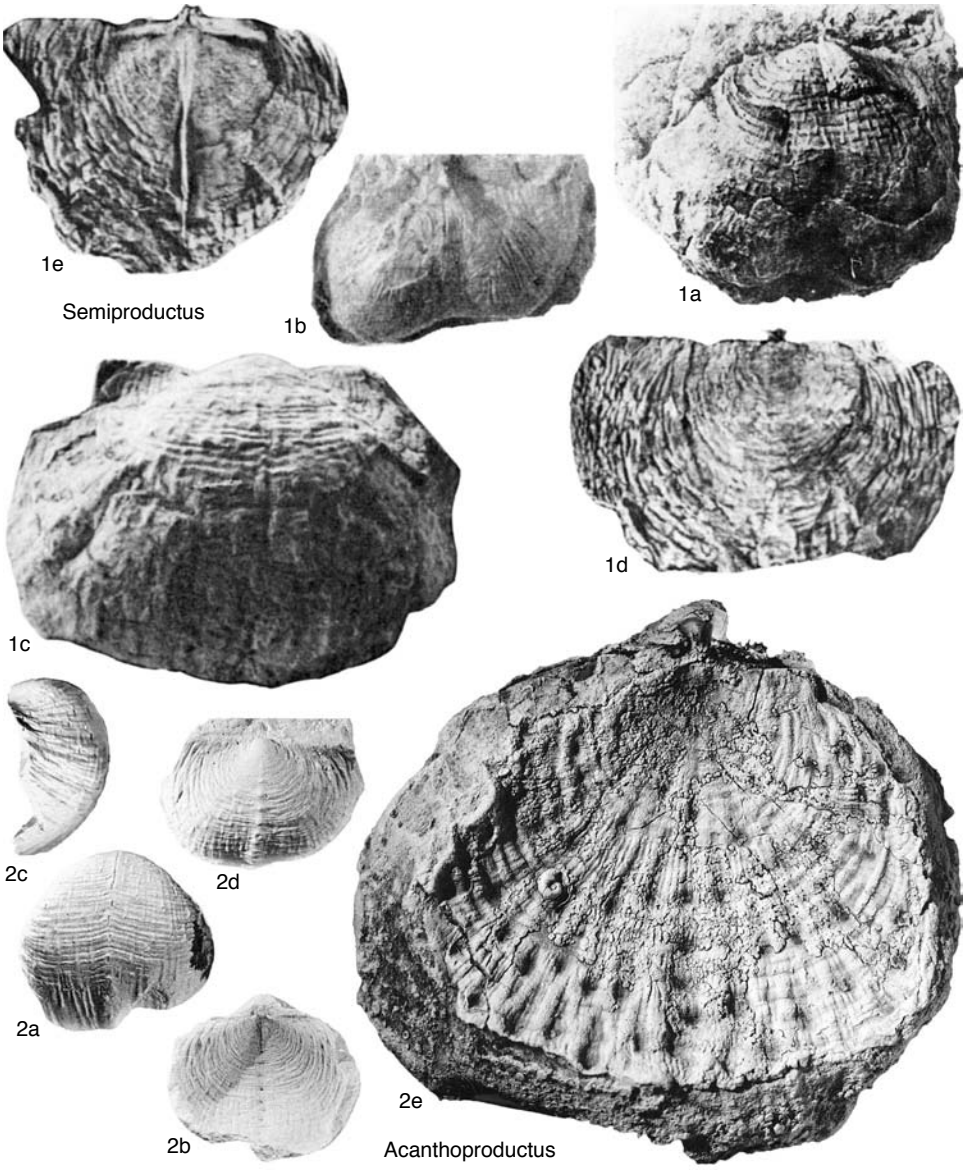

FIG. 326. Productidae (p. 483–485).

FIG. 326,*1a,b.* **S. minax,* lower Tournaisian, Kazakhstan; *a,* holotype, external mold of dorsal valve plus fragment of ventral valve to top right, ×0.8 (Bublichenko, 1956); *b,* internal mold of ventral valve, ×1 (Bublichenko, 1971).——FIG. 326,*1c–e. S. etheridgei* MCKELLAR, uppermost Famennian, Queensland; *c,* holotype, ventral valve exterior, GSQ F4088, ×1.5; *d,e,* replicas of dorsal valve exterior, interior, ×1.5 (McKellar, 1970).

Acanthoproductus MARTYNOVA, 1970, p. 59[49] [**A. bogdanovi;* OD]. Smaller medium size, 25 mm wide; rugae narrow on corpus, elongate spine bases become weak ridges only; dorsal valve with fine radial striations, median fold, sulcus; teeth. *Upper Devonian (Famennian):* Kazakhstan.——FIG. 326,*2a–e.* **A. bogdanovi,* Famennian, Kazakhstan; *a–c,* holotype, anteroventral, dorsal, lateral views, MGU 137/42, ×1; *d,* exfoliated dorsal valve inte-

rior, ×1 (Martynova, 1970); *e,* dorsal valve exterior, ×3 (Lazarev, 1990).

Lomatiphora Roberts, 1971, p. 84 [**L. aquila;* OD]. Ribbing complete, other than at beak, weaker on trail flanges of both valves; spines fine, scattered ventrally; sessile quadrifid cardinal process supported by adductor ridges; weak lateral ridges. *Lower Carboniferous (Tournaisian):* Australia.——Fig. 327,*1a–e. *L. aquila,* lower Tournaisian, Bonaparte Gulf basin; *a,* latex replica of ventral valve exterior viewed posteroventrally, ×1.6; *b,* anteroventral view of ventral valve exterior, ×2; *c,* dorsal valve exterior, ×1.4; *d,* ventral valve internal mold, ×1.5; *e,* holotype, latex replica, dorsal valve interior, CPC 8261a, ×2 (Roberts, 1971).

Margaritiproductus Lazarev, 1986a, p. 67[47] [**Productus (Overtonia) celak* Nalivkin, 1937, p. 61; OD]. Small to medium size; moderately deep corpus, resembling *Semiproductus,* but ribbing confined to trails; teeth small. *Upper Devonian (upper Famennian):* central Asia.——Fig. 328,*3a,b. *M. celak* (Nalivkin), upper Famennian, Kazakhstan; *a,* dorsal valve interior with fragment of ventral valve, small teeth, ×3; *b,* dorsal valve exterior, ×3 (Lazarev, 1986a).——Fig. 328,*3c. Margaritiproductus* sp.; part of dorsal valve interior showing socket, muscle scar, ×3 (new).

Nigerinoplica Lazarev, 1986a, p. 66[45] [**Plicatifera nigerina* Martynova, 1961, p. 87; OD]. Ribbing coarse, commonly confined anteriorly on trail; resembles *Spinocarinifera,* but with teeth. *Upper Devonian (Famennian):* Eurasia, ?North America.——Fig. 327,*3a–c. *N. nigerina* (Martynova), upper Famennian, Kazakhstan; *a,* dorsal view of shell, ×3; *b,* partly exfoliated dorsal valve interior showing greatly reduced tooth, ×3 (Lazarev, 1986a); *c,* oblique view of dorsal interior, ×3 (Lazarev, 1990).

Seminucella Carter, 1987, p. 26 [**Spinocarinifera (Seminucella) parva;* OD]. Small, around 10 mm wide; resembles *Spinocarinifera,* but subparallel flanks, less even ribbing anteriorly; without peglike median lobe of cardinal process, perhaps larger cardinal process pit. *Lower Carboniferous (Tournaisian–lower Viséan):* northern North America.——Fig. 327,*2a–f. *S. parva,* Tournaisian, western Alberta; *a–d,* holotype, viewed ventrally, anteriorly, posteriorly, laterally, GSC 63207, ×3; *e,* dorsal valve exterior, ×3; *f,* dorsal valve interior, ×3 (Carter, 1987).

Spinocarinifera Roberts, 1971, p. 100 [**S. adunata;* OD] [=*Nigeroplica* Nalivkin, 1975, p. 160 (type, *Productus niger* Gosselet, 1888, p. 632); ?*Productus flemingii* de Koninck, 1847a, p. 196, *non* Sowerby, 1812, p. 155, *sensu* Gosselet, 1880, pl. 6, fig. 16]. Small size; outline subquadrate with small but well-differentiated ears, profile strongly convex; dorsal valve weakly concave, geniculate with no spines; ribbing well formed anteriorly; cardinal process trifid with pit small, variable; cardinal ridges diverge from hinge close to ears. *Lower Carboniferous (lower Tournaisian):* Australia, Eurasia, northern Africa, North America.——Fig. 328,*1a–e. *S. adunata,* Hastarian, Bonaparte Gulf, Australia; *a–d,* holotype viewed ventrally, dorsally, posteriorly, laterally, CPC 8564, ×2; *e,* dorsal valve interior, ×4 (Roberts, 1971).

Yanguania Yang Shi-pu, 1978, p. 107 [**Spinulicosta dushanensis* Yan Shi-pu, 1964, p. 87; OD]. Similar to *Spinocarinifera,* possibly differing by weak rugae posteriorly, weakly developed ribbing anteriorly. *Lower Carboniferous (Tournaisian):* southern China.——Fig. 328,*2a–d. *Y. dushanensis,* lower Tournaisian, Yanguan, Guizhou; *a,* shell viewed anteroventrally, ×2; *b,* shell viewed dorsally, ×1; *c,d,* shell viewed anteriorly, laterally, ×1 (Yang Shi-pu, 1978).

Tribe TYLOPLECTINI Termier & Termier, 1970

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 928, *ex* Tyloplectidae Termier & Termier, 1970, p. 457]

Ribbed, other than at beak; additional striae dorsally; ventral spines large near hinge and on flanks, probably absent dorsally. *Lower Permian (Artinskian)–Upper Permian (Capitanian).*

Tyloplecta Muir-Wood & Cooper, 1960, p. 290 [**Productus scabriculus* mut. *nankingensis* Frech, 1911, p. 163; OD] [=*Nankinoproductus* Huang & Tseng, 1948, p. 254, *nom. nud.*]. Medium size, planoconvex with short adult trail; hinge equal to maximum width; elongate spine bases posteriorly, becoming ribs at midlength of corpus; rugae present posterolaterally on both valves; spines near hinge, scattered on venter; cardinal process with wide shaft; weak lateral ridges, ear baffles; shell substance thick. *Lower Permian (Artinskian–Kungurian):* China, southern Europe, ?Indonesia.——Fig. 329*a–g. *T. nankingensis,* Lower Permian, Chihsian Formation, Sichuan; *a–c,* specimen viewed ventrally, posteriorly, laterally, ×1; *d,* shell viewed dorsally, ×1; *e,* ventral valve interior, ×1; *f,* dorsal valve interior, ×1; *g,* detail of dorsal valve external ornament, ×2 (Muir-Wood & Cooper, 1960).

Araxilevis Sarytcheva in Sarytcheva & Sokolskaya, 1965, p. 221 [**Productus intermedius* Abich, 1878, p. 27; OD]. Medium to large, ventral profile strongly convex with weak geniculation, anterior trail lamellose; median sulcus weak; ribbing absent, rugae weak on disks, ears; spine bases swollen, rounded posteriorly, elongate on ventral trail; dorsal valve weakly concave with short trail; cardinal process large, trifid; lateral ridges diverge slightly from hinge, continue weakly separating ears and to lateral margins; valves thick shelled, finely striate on exfoliated surfaces. *Upper Permian (upper Capitanian):* Transcaucasus.——Fig. 330,*1a–e. *A. intermedius* (Abich), upper Capitanian, Transcaucasus; *a,b,* lectotype, viewed laterally, dorsally, LGE 24/99, ×1; *c,* anterior view, ×1; *d,* ventral view, ×1; *e,* dorsal valve interior, ×1 (Sarytcheva & Sokolskaya, 1965).

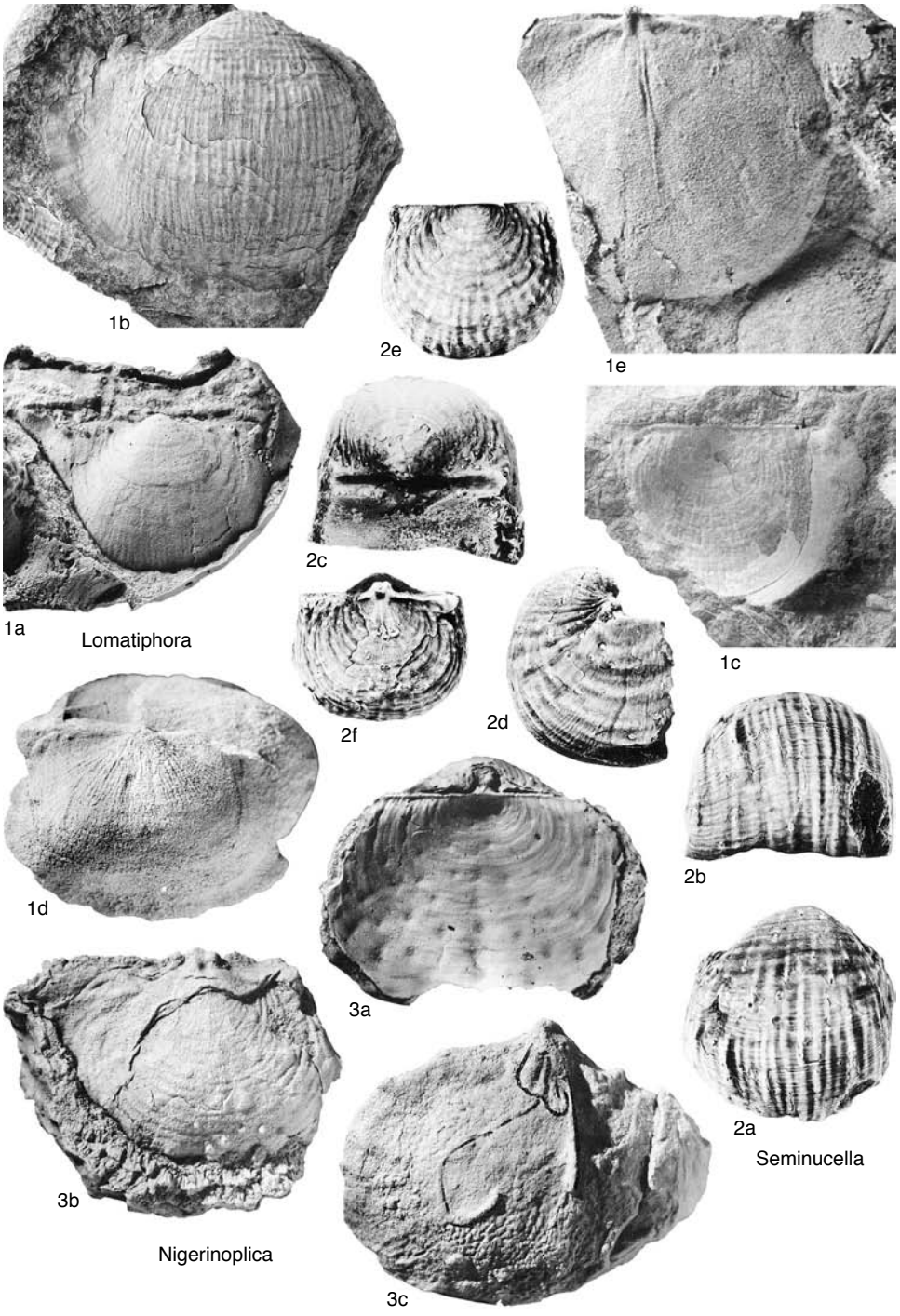

FIG. 327. Productidae (p. 485).

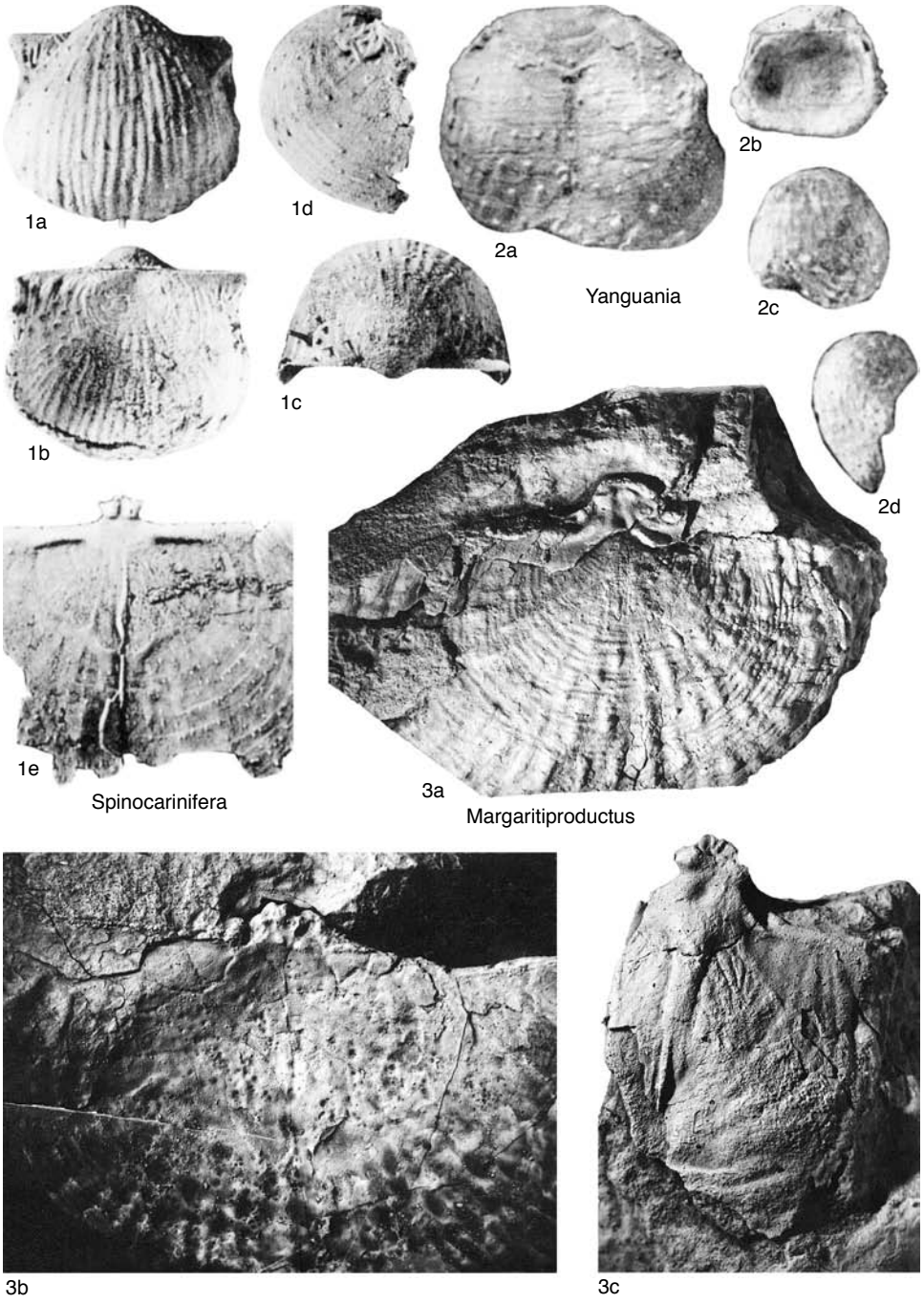

FIG. 328. Productidae (p. 485).

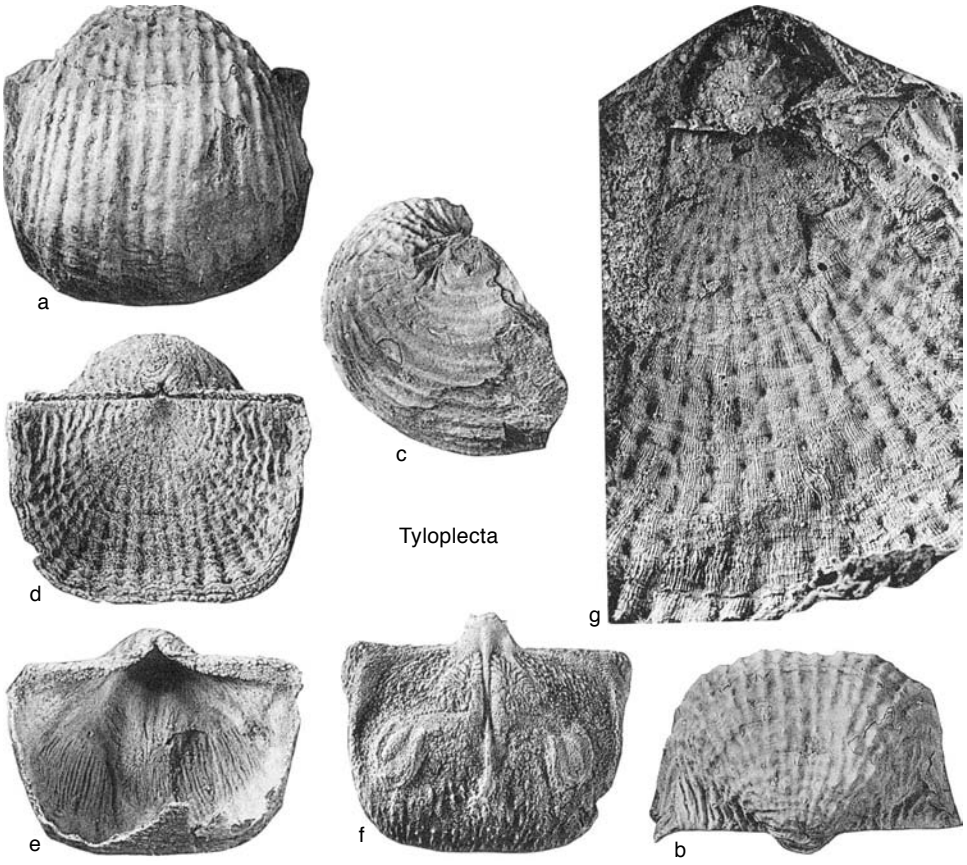

FIG. 329. Productidae (p. 485).

Pseudoantiquatonia ZHAN & WU, 1982, p. 98 [**P. mutabilis;* OD]. Medium size, planoconvex corpus with trails; spine distribution, ribbing as in *Tyloplecta,* but finer. *lower Upper Permian (Kazanian):* China (Xizang, Tibet).——FIG. 330,*2a–d.* **P. mutabilis,* Upper Permian, Xiala Formation, Xainza, Tibet; *a,b,* anterior, lateral views, ×1; *c,d,* deeply exfoliated dorsal valve interior, anterior, ×1 (Zhan & Wu, 1982).

Subfamily DICTYOCLOSTINAE Stehli, 1954

[Dictyoclostinae STEHLI, 1954, p. 316]

Medium to large size; trails long, simple; ribbing complete with reticulation posteriorly; ventral spines commonly stout halteroid, dorsal spines absent; dorsal adductor scars positioned close to hinge line; marginal structures absent or weak. *Lower Carboniferous (Viséan)–Upper Permian (Tatarian).*

Dictyoclostus MUIR-WOOD, 1930, p. 103 [**Anomites semireticulatus* MARTIN, 1809, p. 7; OD]. Medium to commonly large; ribbing entire, ginglymus absent; spines clustered at ears, otherwise weak; cardinal ridges weak, not extended as ear baffles. *Lower Carboniferous (Viséan):* Europe, ?Asia, ?northern Africa.——FIG. 331*a–d.* **D. semireticulatus* (MARTIN), upper Viséan, Yorkshire; neotype, ventral, dorsal, posterior, lateral views, BMNH B45691, ×1 (new).——FIG. 331*e. D. pinguis* (MUIR-WOOD), upper Viséan, Yorkshire; wax replica of dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Auloprotonia MUIR-WOOD & COOPER, 1960, p. 273 [**A. aulacophora;* OD]. Somewhat resembling *Dictyoclostus* in ornament, but less strongly rugose, spines weaker, but with pair of strong spines on ears; trail with gutter; cardinal ridges extending to weak ear baffles. *Lower Carboniferous (middle Viséan):* North America.——FIG. 332,*1a–f.* **A. aulacophora,*

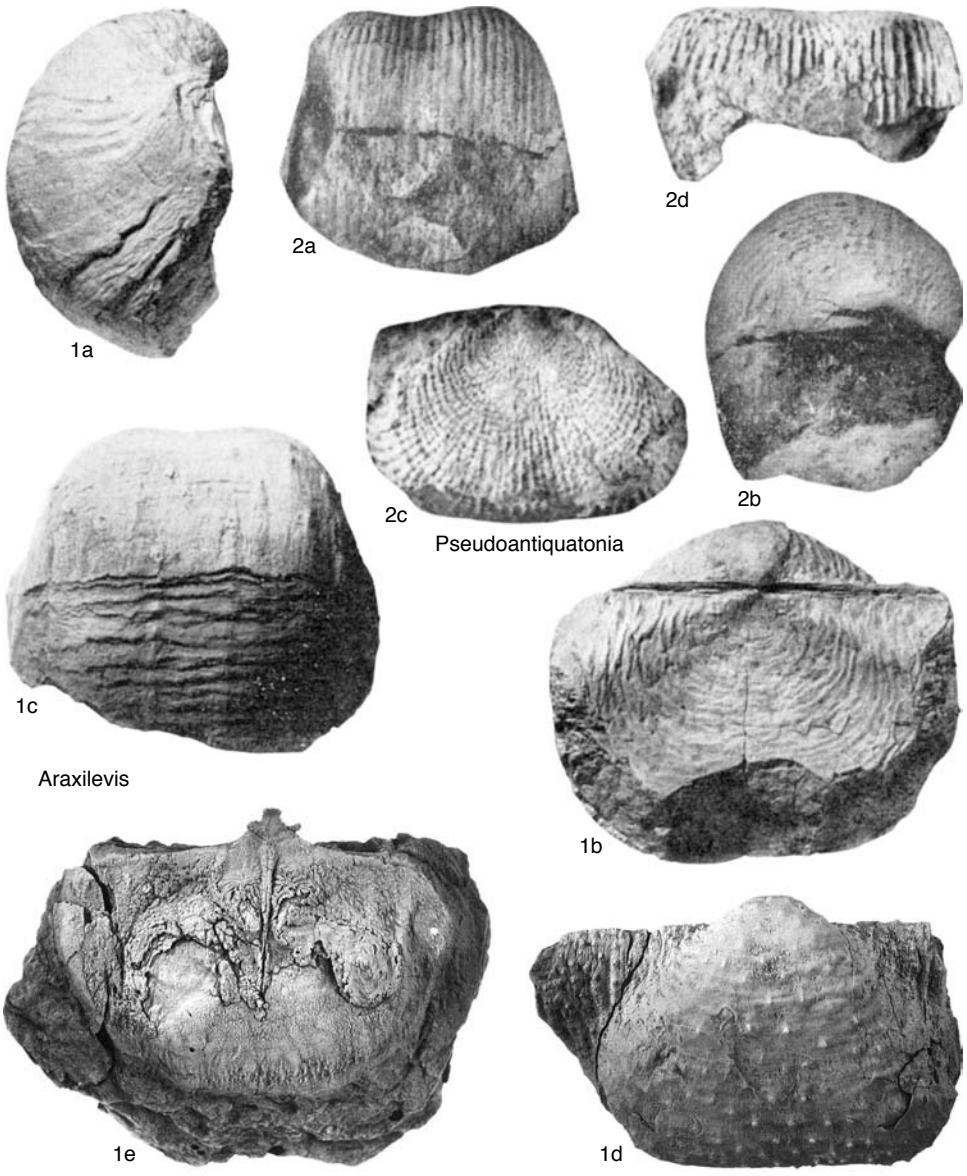

FIG. 330. Productidae (p. 485–488).

middle Viséan, Oklahoma; *a–c,* holotype, ventral, lateral, lateral oblique views, USNM 123976e, ×1; *d,* dorsal valve exterior, ×1; *e,* latex replica of dorsal valve interior, ×1; *f,* posterior view of ventral valve internal mold, ×1 (Muir-Wood & Cooper, 1960).

Callytharrella ARCHBOLD, 1985, p. 19 [**Dictyoclostus callytharrensis* PRENDERGAST, 1943, p. 13; OD]. Resembling *Stereochia,* but less strongly geniculate, weaker ear baffles, and with ribs on adult ears. *Lower Permian (Sakmarian):* Western Australia, Himalayas.——FIG. 333,*2a–e.* **C. callytharrensis* (PRENDERGAST), Lower Permian; *a,b,* ventral valve exterior, ventral valve viewed laterally, Jimba Jimba Calcarenite, Carnarvon Basin, Western Australia, ×1; *c–e,* ventral view, dorsal view, incomplete dorsal valve interior, Callytharra Formation, ×1 (Archbold, 1985).

Chaoiella FREDERICKS, 1933, p. 27 [**Productus semireticularis* var. *gruenewaldti* KROTOW, 1888, p. 546; OD]. Ears large; strong ventromedian sulcus,

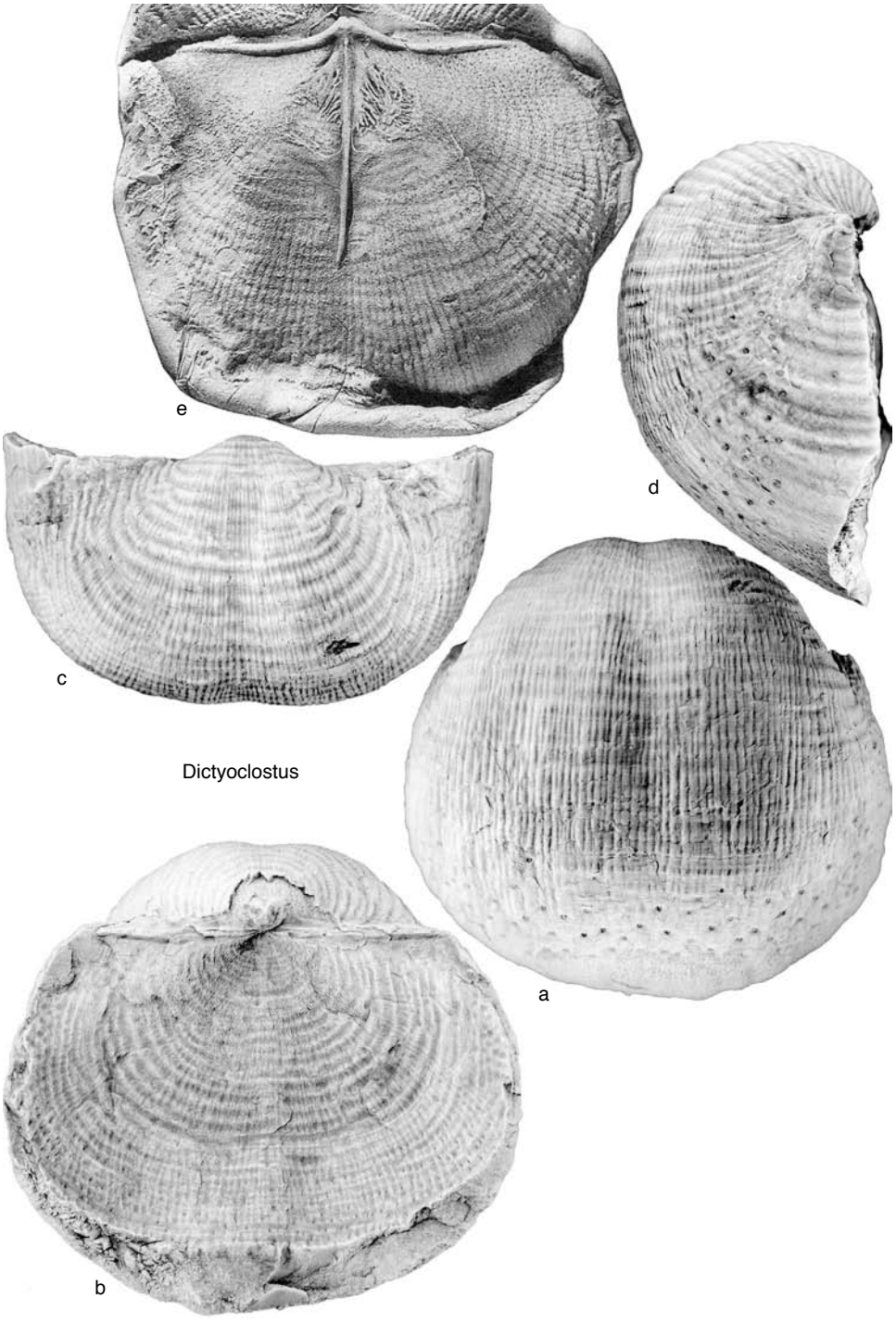

FIG. 331. Productidae (p. 488).

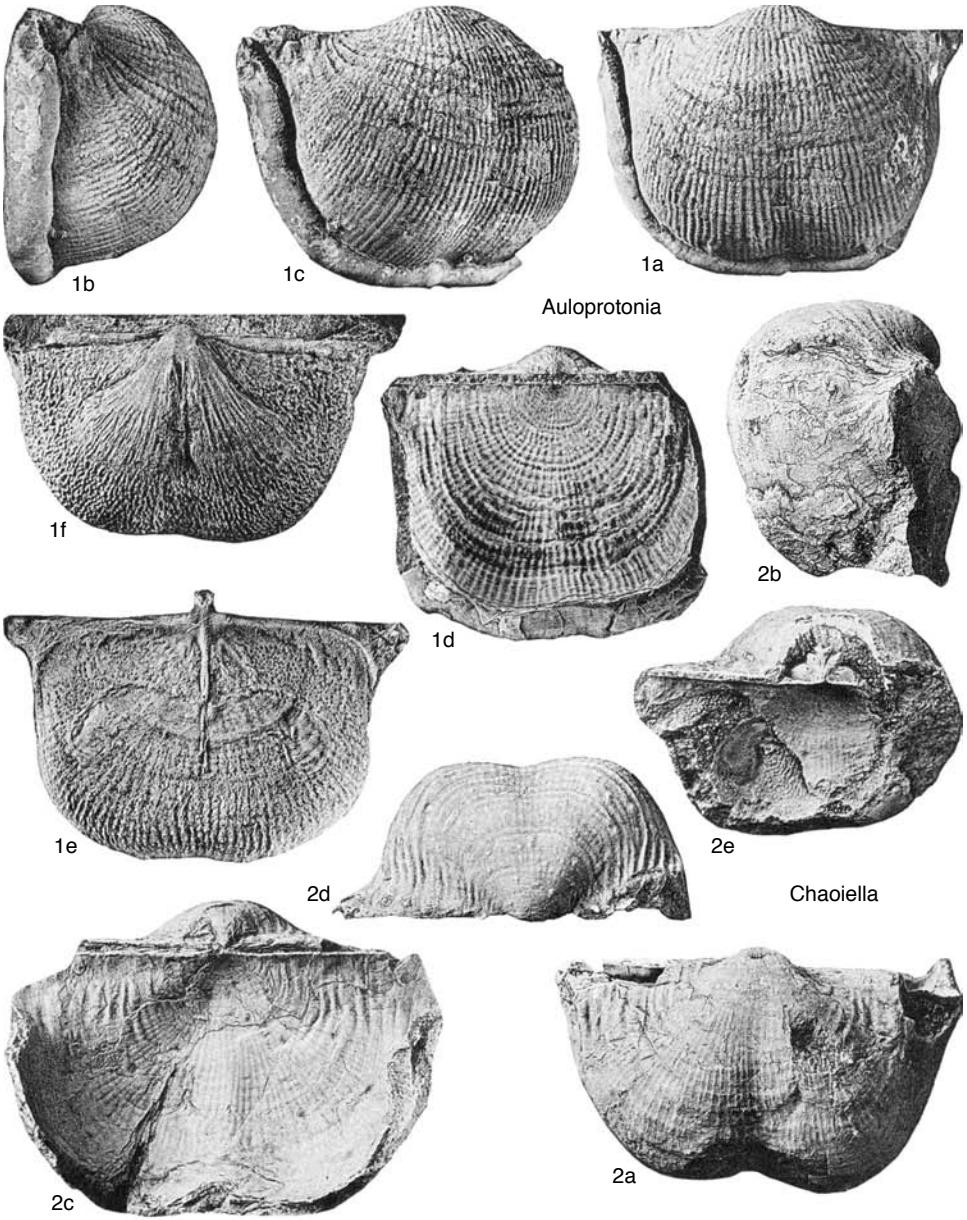

FIG. 332. Productidae (p. 488–491).

ribbing weak or absent on trails, reticulation relatively weak; strong cardinal ridges, dorsal adductor scars dendritic, placed relatively anteriorly. *Lower Permian (Artinskian):* Eurasia.——FIG. 332,*2a–e.* **C. gruenewaldti* (KROTOW), Artinskian, Russia; *a–c,* ventral, lateral, dorsal views of large specimen, ×1; *d,* posterior view of ventral exterior, ×1; *e,* posterodorsal view of specimen showing cardinal process, ×1 (Muir-Wood & Cooper, 1960).

Dasysaria COOPER & GRANT, 1969, p. 9 [**D. undulata;* OD]. Resembles *Reticulatia,* but with more densely scattered ventral spines and clusters on ears. *Lower Permian (Sakmarian):* USA.——FIG. 333,*1a–f.* **D. undulata,* Lower Permian, Hueco Formation, Texas;

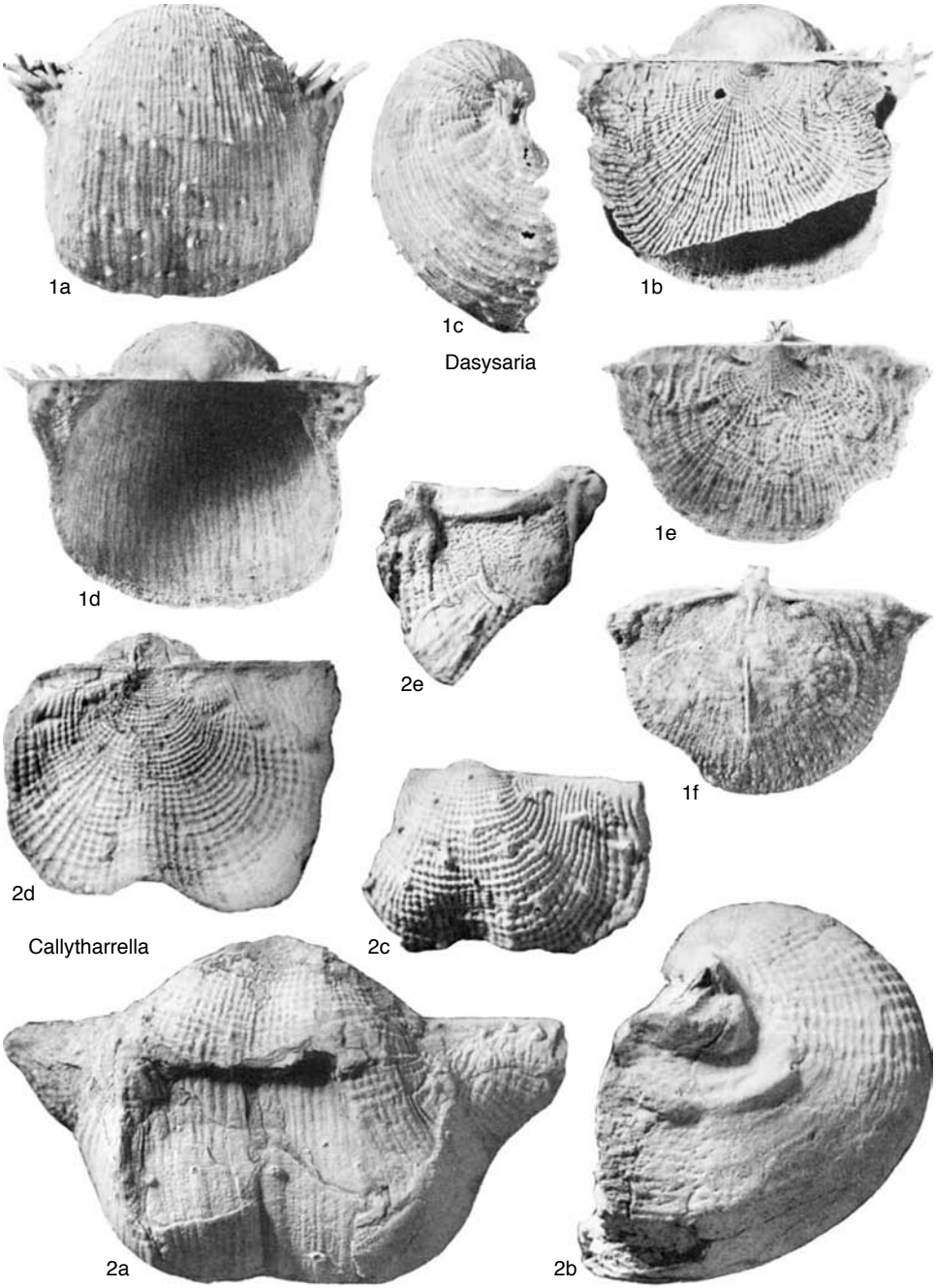

FIG. 333. Productidae (p. 489–492).

a–c, shell viewed ventrally, dorsally, laterally, ×1; *d,* ventral valve interior, ×1; *e,f,* dorsal valve exterior, interior, ×1 (Cooper & Grant, 1975).

Kunlunia WANG ZHI, 1983, p. 308 [**K. aspera;* OD]. Resembles *Liraplecta,* but differs in having large extended ears on which are clusters of spines. *Lower*

FIG. 334. Productidae (p. 492–494).

Permian (Asselian–Kungurian): China.——FIG. 334,*2a–c.* **K. aspera,* lower Chihsian, Kunlun Mountains, Xinjiang; *a,b,* holotype, ventral, lateral views, XBRB 355, repository unknown, ×1; *c,* incomplete dorsal valve interior showing part of external mold, ×1 (new).

Liraplecta JIN & SUN , 1981, p. 136 [**Productus richthofeni* CHAO, 1927b, p. 60; OD]. Resembles *Stereochia,* but has dorsal capillae plus normal ribbing. *Lower Permian (Asselian–Sakmarian):* China.——FIG. 334,*1a–e.* **L. richthofeni* (CHAO), Sakmarian, Lizha Formation, Tibet; *a,b,* anterior,

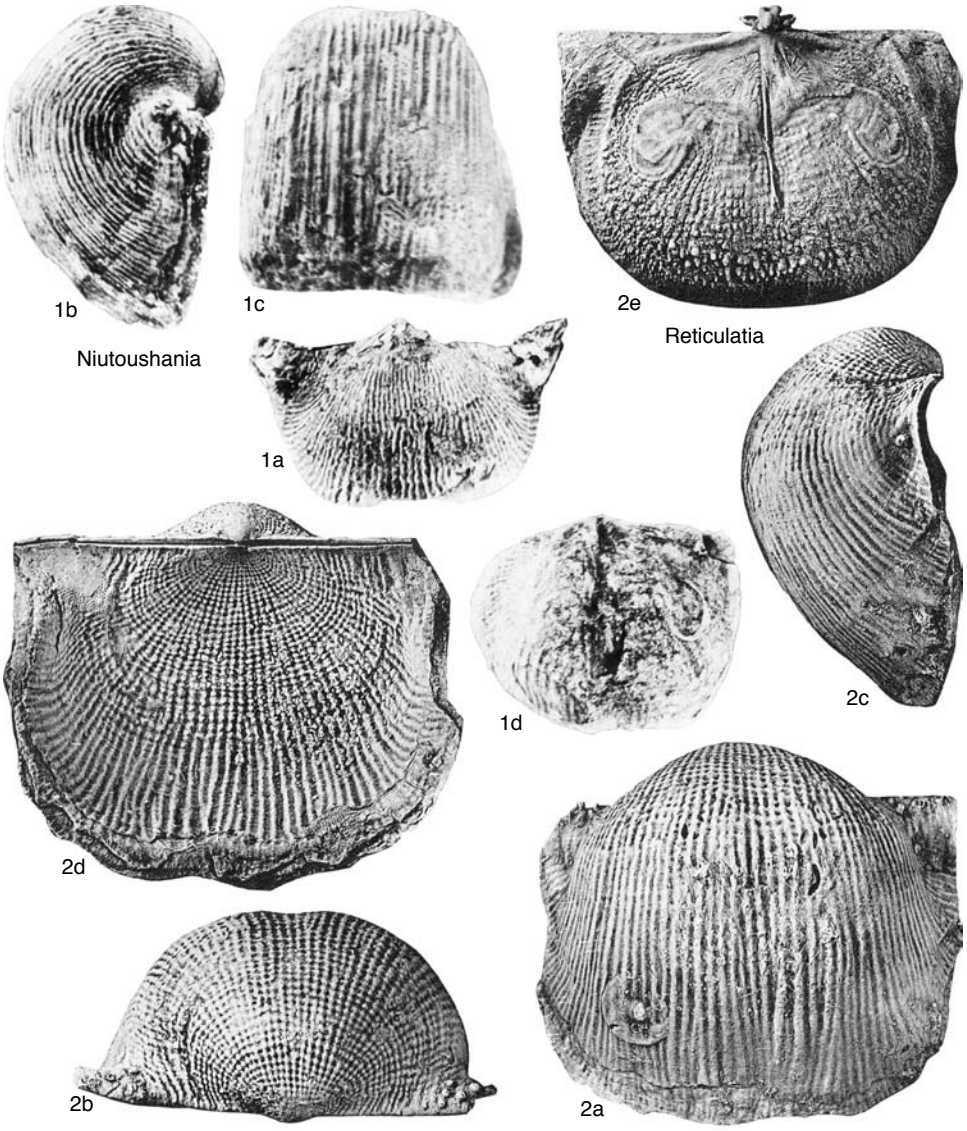

FIG. 335. Productidae (p. 494–496).

lateral views of specimen, ×1; *c,d,* ventral, dorsal views of shell, ×1; *e,* detail of dorsal external ornament, ×10 (Jin & Sun, 1981).

?Niutoushania LIAO, 1984, p. 281[284][**N. niutoushanensis;* OD]. Medium size, elongate with hinge wider than corpus width; profile strongly, evenly convex; median sulcus weak; dorsal valve with flattened posterior disk, geniculate, with trail; ribbing fine, somewhat irregular posteriorly, widening anteriorly; rugae seemingly absent; spines reported at hinge only; dorsal cardinal ridges extend as weak marginal ridge. Possibly a dictyoclostid but seemingly no reticulation. *Upper Permian (Tatarian):* China.——FIG. 335,*1a–d.* **N. niutoushanensis,* Longtan Formation, Anhui Province; *a,b,* holotype, viewed posteriorly, laterally, NIGP 71140, ×1; *c,* anterior view of shell, ×1; *d,* incomplete dorsal valve interior, ×1 (new).

Ozora CARTER, 1990, p. 226 [**O. genevievensis;* OD]. Spines ventral, near hinge, on flanks, rare on disk, but in concentric bands on trail with widened ribs; reticulation prominent posteriorly; adult dorsal disk with marginal ridges. *Lower Carboniferous (lower Viséan):* central North America.——FIG. 336,*1a–e.*

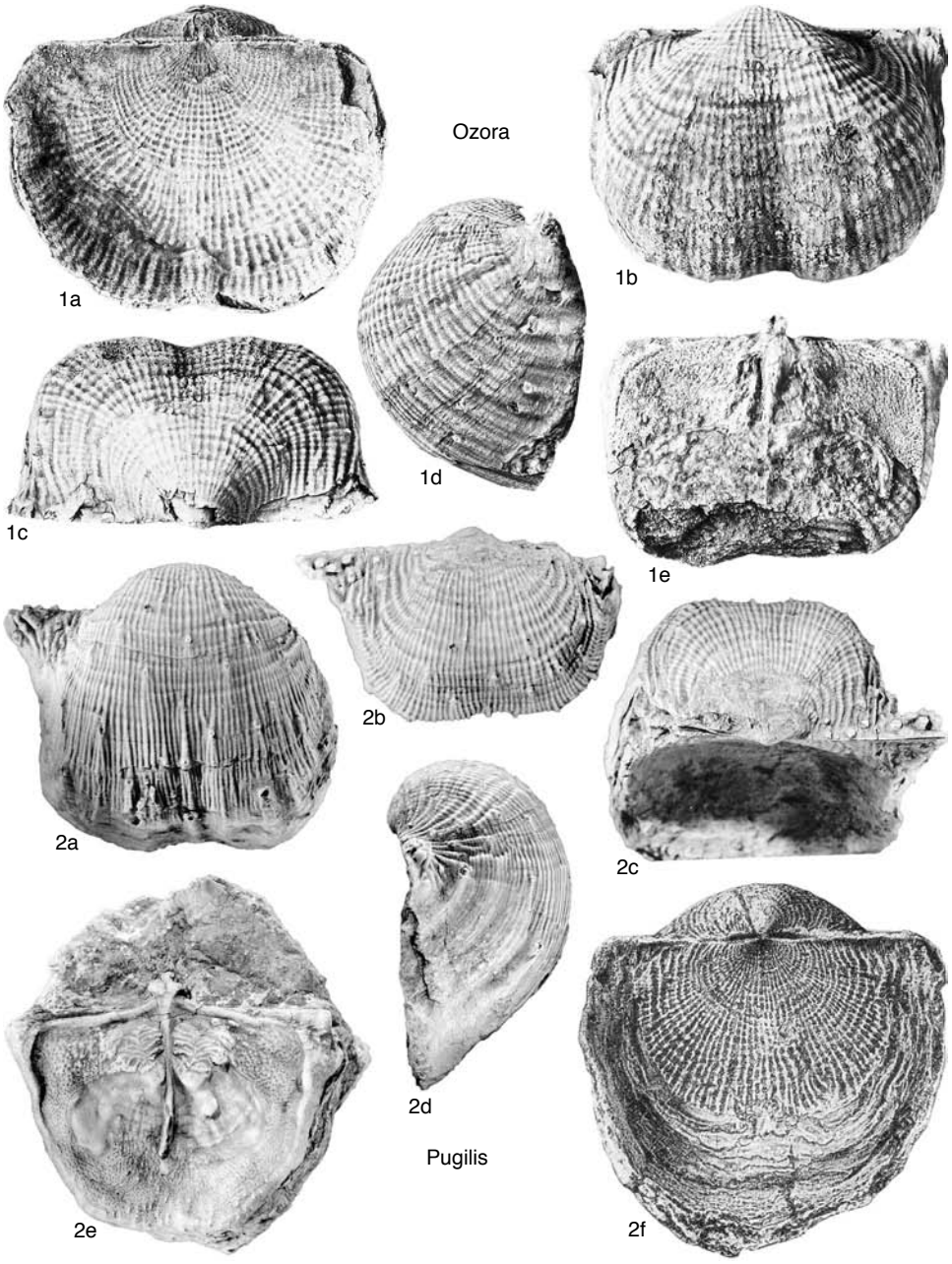

FIG. 336. Productidae (p. 494–496).

**O. genevievensis,* lower Viséan, Missouri; *a,* holotype, dorsal valve exterior, CMNH 34893, ×1; *b,c,* ventral valve exterior viewed ventrally, posteriorly, ×1; *d,* ventral valve viewed laterally, ×1; *e,* incomplete dorsal valve interior, ×1 (Carter, 1990).

Pugilis SARYTCHEVA, 1949, p. 104 [**Producta pugilis* PHILLIPS, 1836, p. 215; OD] [=*Pugilus* SARYTCHEVA in SARYTCHEVA & SOKOLSKAYA, 1952, p. 77, obj.]. Medium size; deep corpus; ribs regular posteriorly, but irregular and commonly weak on trails,

enlarged or branched distal to spine bases; dorsal valve commonly lamellose on trail; lateral ridges strong, near hinge, continue as ear baffles and subperipheral ridge laterally. *Lower Carboniferous (upper Viséan–lower Serpukhovian):* Europe, northern Africa.——Fig. 336,*2a–f.* **P. pugilis* (Phillips); *a–d,* anterior, ventral, posterior, lateral views of shell, upper Viséan, north Wales, ×1; *e,* dorsal valve interior, Northumberland, ×1 (new); *f,* dorsal view of shell exterior showing series of dorsal trails, Serpukhovian, Renfrewshire, Scotland, ×1 (Muir-Wood & Cooper, 1960).

Reticulatia Muir-Wood & Cooper, 1960, p. 284 [**Productus huecoensis* King, 1931, p. 68; OD]. Resembles *Dictyoclostus,* but differs in having ginglymus, lateral ridges near the hinge that may continue weakly as marginal ridges with endospines anteriorly. *Upper Carboniferous (Bashkirian)–Lower Permian (lower Artinskian):* North America, Europe, Asia.——Fig. 335,*2a–e.* **R. huecoensis* (King), Lower Permian, Hughes Creek Shale, Nebraska; *a–d,* shell viewed ventrally, posteriorly, laterally, dorsally, ×1; *e,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Rugatia Muir-Wood & Cooper, 1960, p. 285 [**Productus paraindicus* McKee, 1938, p. 241; OD]. Medium size, transverse with large, well-differentiated ears; median sulcus shallow, extending to valve margins; rugae weak on ears, some on dorsal disk; ribbing variable, originates anteriorly on disks, weak, irregular, coarse to strong anteriorly on corpus; spines thick, in lines separating umbo from ears, in clusters on ears, widely scattered on corpus, also with small spines; ventral adductor platform high; cardinal ridges lost at ears. *Lower Permian (Artinskian):* southern USA.——Fig. 337,*2a–e.* **R. paraindica* (McKee), Lower Permian, Leonard Formation, Texas; *a,b,* anterior, lateral views, ×1; *c,* dorsal view, ×1; *d,* dorsal valve interior, ×1; *e,* disarticulated dorsal, ventral valves, ×1 (Muir-Wood & Cooper, 1960).

Stereochia Grant, 1976, p. 150 [**S. litostyla;* OD]. Medium size, widest at hinge; disks of both valves reticulate, trails costate; spines thick, but few, single on ears, venter; ventral adductor platforms raised, dendritic; diductor scars strongly striated; cardinal process trifid, shaft short, continuous with median septum; lateral ridges, ear baffles, latter strong in ventral valve. *Lower Permian (upper Artinskian):* Thailand, Indonesia, ?northeastern Asia.——Fig. 337,*1a–e.* **S. litostyla,* upper Artinskian, Ko Muk, Thailand; *a,b,* holotype, viewed laterally, dorsally, USNM 212592, ×0.75; *c,d,* ventral valve exterior, interior, ×1; *e,* dorsal valve interior, ×1 (Grant, 1976).

Subfamily BUXTONIINAE Muir-Wood & Cooper, 1960

[Buxtoniinae Muir-Wood & Cooper, 1960, p. 255]

Size varied, but with corpus cavity deep; ribbing on trails, commonly on corpus; spines dense on both valves, but may be restricted anteriorly on dorsal valve; elongate cardinal process pit seldom absent; dorsal muscle scars separated from hinge region. *Lower Carboniferous (Tournaisian)–upper Lower Permian (Roadian).*

Tribe BUXTONIINI Muir-Wood & Cooper, 1960

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 928, *ex* Buxtoniinae Muir-Wood & Cooper, 1960, p. 255] [=Kochiproductini Lazarev, 1985, p. 67]

Dorsal trail commonly short, bordering structures (flanges) sporadic; ribs cover both valves, other than in Tournaisian, when smooth posteriorly; rugae irregular, may dominate ribs; spines on ventral valve uniformly distributed, commonly from swollen bases; buttress plates and pit present, but variable. *Lower Carboniferous (Tournaisian)–Lower Permian (Asselian, ?Sakmarian).*

Buxtonia Thomas, 1914, p. 259 [**Anomites scabriculus* Martin, 1809, p. 8; OD, species declared invalid, ICZN, 1956a; =*Productus scabriculus* J. Sowerby, 1814 in 1812–1815, p. 157; SD, ICZN, Opinion 420, 1956b, p. 143]. Medium size; ventral posterior ribbing characterized by swollen elongate spine bases; cardinal ridges to ears, cardinal process narrow, dorsally reflexed. *Carboniferous (Viséan–Serpukhovian):* Europe, America, Australia, ?Far East.——Fig. 338,*3a–c.* **B. scabricula* (J. Sowerby), upper Viséan, Derbyshire; *a–c,* lectotype, ventral, dorsal, lateral views, BMNH B 60954, ×1 (new).——Fig. 338,*3d,e. Buxtonia* sp., Lower Carboniferous, Pendleian, Northumberland; *d,* dorsal view of internal mold, ×1; *e,* latex replica of dorsal valve interior, ×1.5 (new).

?Bellaclathrus Winters, 1963, p. 26 [**B. spinosus;* OD]. Medium size, corpus outline subquadrate; corpus profile almost planoconvex with strong dorsal geniculation; trails short; ventral sulcus weak; disks reticulate; spines fine on both valves plus rows of thick spines at ventral ears; cardinal process trifid with short shaft internally; lateral ridges reach ears, medium septum divided posteriorly. *Lower Permian:* USA.——Fig. 338,*1a–f.* **B. spinosus,* Lower Permian, Fort Apache Limestone, Arizona; *a–c,* holotype, viewed ventrally, dorsally, laterally, AMNH 27995/3:1, ×1; *d,* ventral view, ×1; *e,* part of dorsal valve interior, ×2; *f,* exterior showing cardinal process, ×3 (Winters, 1963).

Buxtonioides Mendes, 1959, p. 43 [**Productus amazonicus* Katzer, 1903, p. 264; OD] [=*Gemmulicosta* Waterhouse in Bamber & Waterhouse, 1971, p. 210 (type, *G. gemma;* OD)]. Similar to *Kochiproductus,* but apparently lacking bordering flange, internal ventral posteromedian ridge, and without adult buttress plates. *Upper Carboniferous*

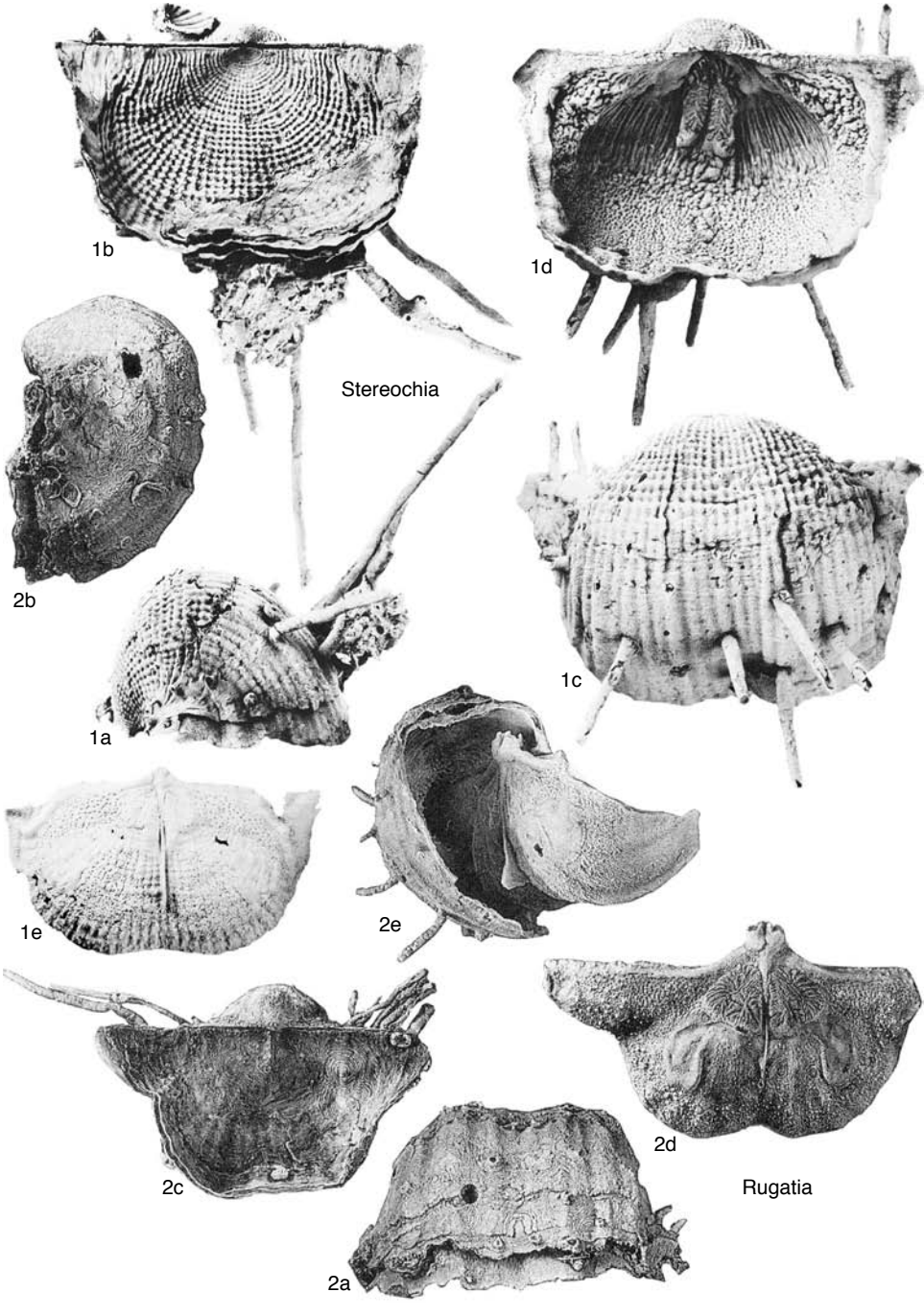

FIG. 337. Productidae (p. 496).

(Bashkirian–Gzhelian): South America, Canada, Russia.——FIG. 339*a–c.* **B. amazonicus* (KATZER), Morrowan–Desmoinesian, Brazil; *a,b,* ventral, dorsal views of complete specimen, ×1; *c,* details of ventral valve exterior, ×5 (Mendes, 1959).——FIG. 339*d. B. gemma* WATERHOUSE, Moscovian, western

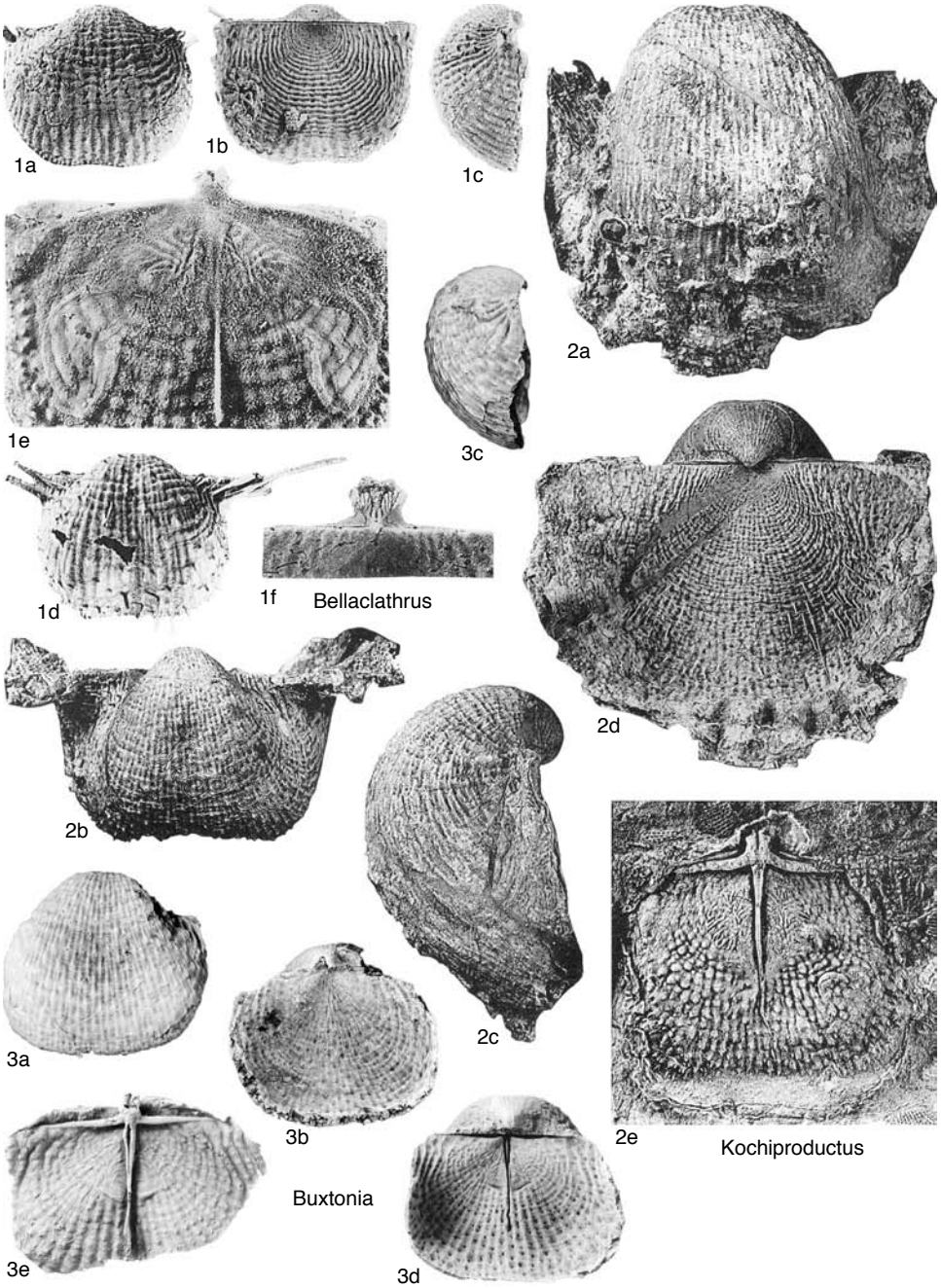

FIG. 338. Productidae (p. 496–500).

Alberta; ventral view of ventral valve, ×1 (Bamber & Waterhouse, 1971).——FIG. 339*e. B. gjeliensis* (IVANOV), Gzhelian, Gzel, near Moscow; dorsal valve exterior plus interior of ventral umbo showing cardinal process, lack of ventral ridge, ×1 (Lazarev, 1990).

Flexaria MUIR-WOOD & COOPER, 1960, p. 258 [**Productus arkansanus* GIRTY, 1910, p. 216; OD].

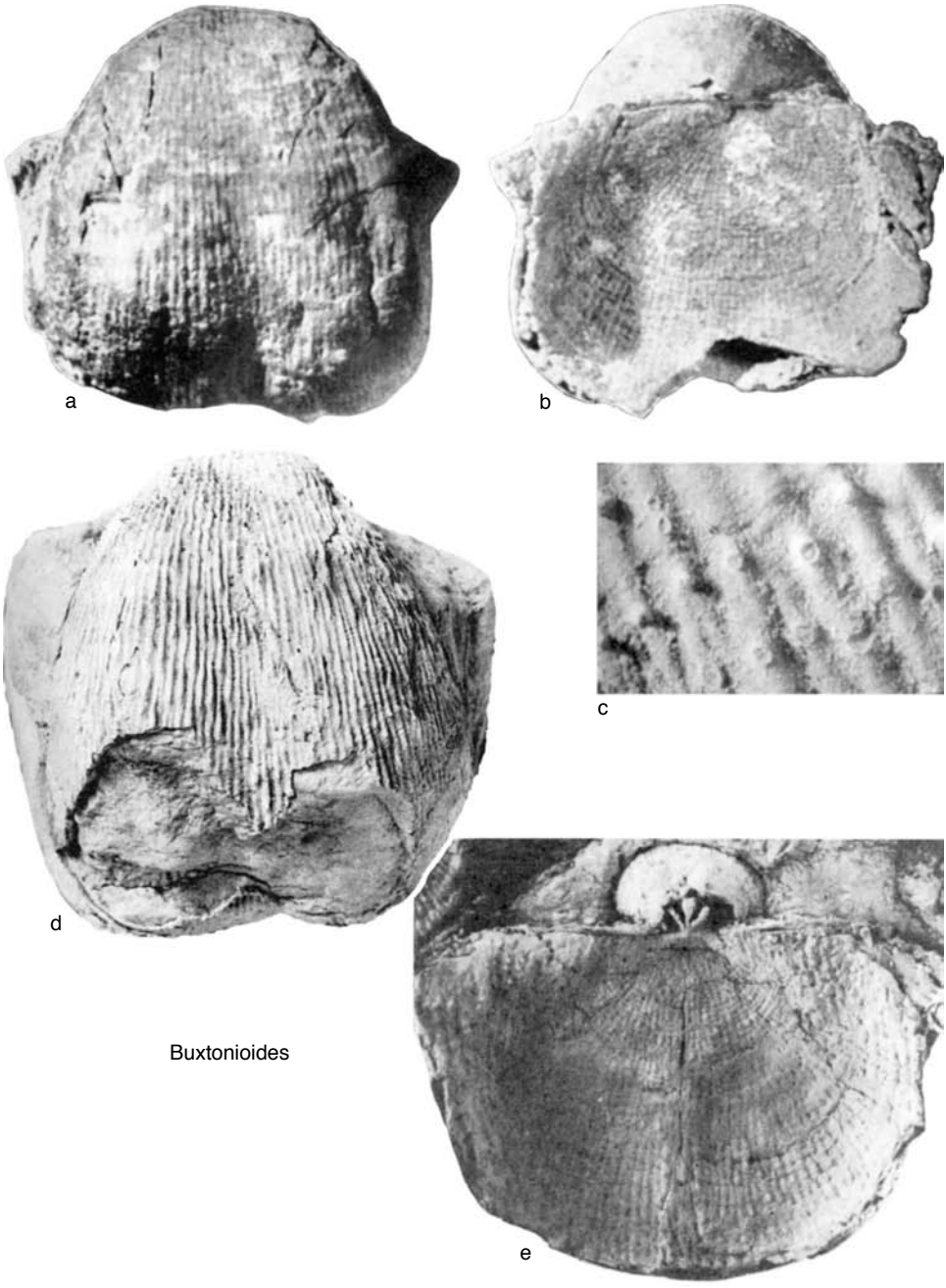

FIG. 339. Productidae (p. 496–498).

Resembles *Buxtonia,* but differing in its flat dorsal disk, geniculate trail; short lateral ridges, more elongate adductor muscle scars. *Lower Carboniferous (upper Viséan–lower Serpukhovian):* North America.——FIG. 340,*2a–f. *F. arkansana* (GIRTY), upper Viséan–lower Serpukhovian; *a,* dorsal view of complete specimen, Missouri, ×1; *b–d,* ventral, posterior, lateral views of complete specimen, Missouri,

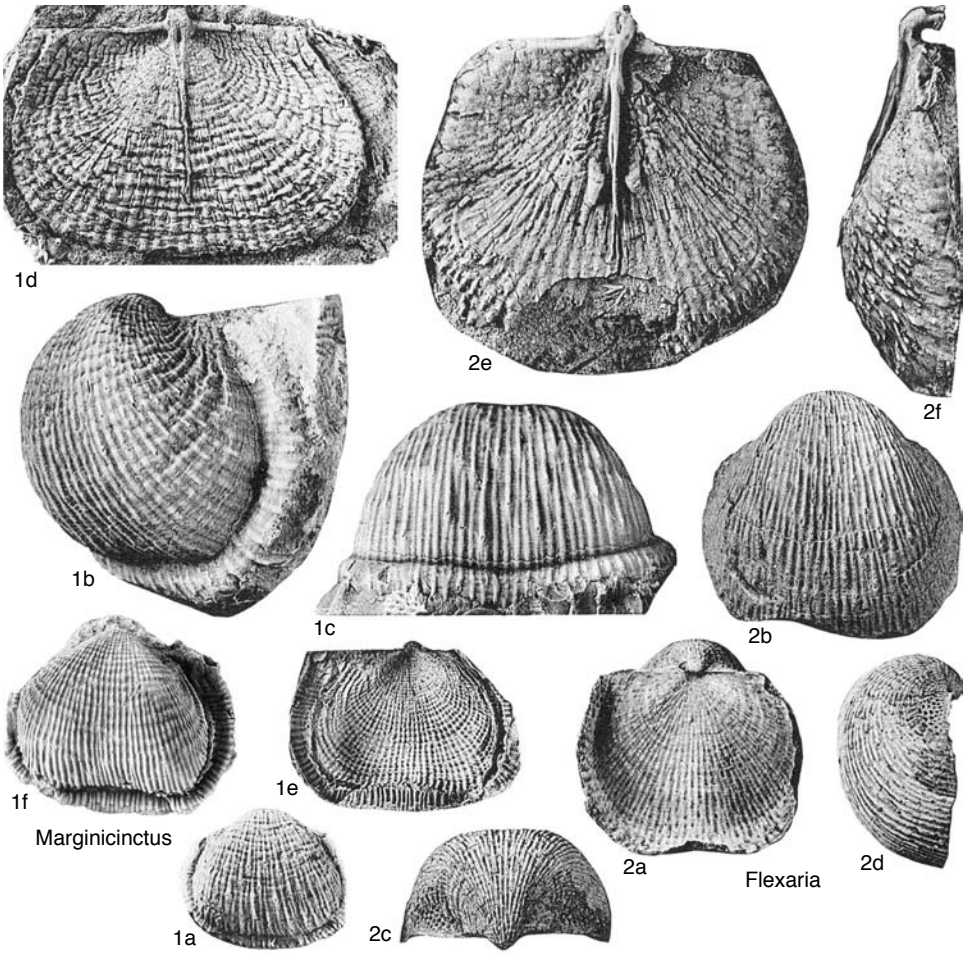

FIG. 340. Productidae (p. 498–501).

×1; *e,* dorsal valve interior, Oklahoma, ×2; *f,* lateral view of dorsal valve, Oklahoma, ×2 (Muir-Wood & Cooper, 1960).

Kochiproductus DUNBAR 1955, p. 107, *nom. nov. pro. Tschernyschewiella* FREDERICKS, 1924, p. 20, *non* VON TOLL, 1899 [**Productus porrectus* KUTORGA, 1844, p. 96; SD MUIR-WOOD & COOPER, 1960, p. 260]. Medium to large, with large ears, commonly with anterolateral flange; ribbing weak on ventral valve, accentuated by closely spaced elongate spine bases; rugae more prominent on dorsal valve; spines recumbent from swollen bases, semierect on ears and ventral trail, cover dorsal valve; low ventral median ridge from umbo to anterior of muscle field; cardinal ridges long, buttress plates with pit in adults. *Lower Permian (Asselian, ?lower Sakmarian):* Arctic regions, Mongolia, North and South America.——FIG. 338,*2a–e. K. peruvianus* (D'ORBIGNY), Lower Permian, Hueco Formation, Texas; *a–d,* shell viewed ventrally, posteriorly, laterally, dorsally, ×0.75; *e,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Labriproductus COOPER & MUIR-WOOD, 1951, p. 195, *nom. nov. pro Worthenella* GIRTY, 1938b, p. 442, *non* WALCOTT, 1911 [**Productus wortheni* HALL, 1858a, p. 638; OD]. Smaller than *Buxtonia,* but with stronger ribs, small bordering flange, no ventromedian sulcation. *Lower Carboniferous (upper Tournaisian–Viséan):* central North America.——FIG. 341,*1a–e. *L. wortheni* (HALL), upper Tournaisian, Missouri; *a–d,* ventral, lateral, anterior, posterior views of specimen, ×2; *e,* latex replica of dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Marginicinctus SUTTON, 1938, p. 561 [**Productus marginicinctus* PROUT, 1857, p. 43; OD]. Resembles *Buxtonia,* but smaller, with bordering reflexed flange, internal marginal ridges in both valves. *Lower Carboniferous (middle Viséan):* North

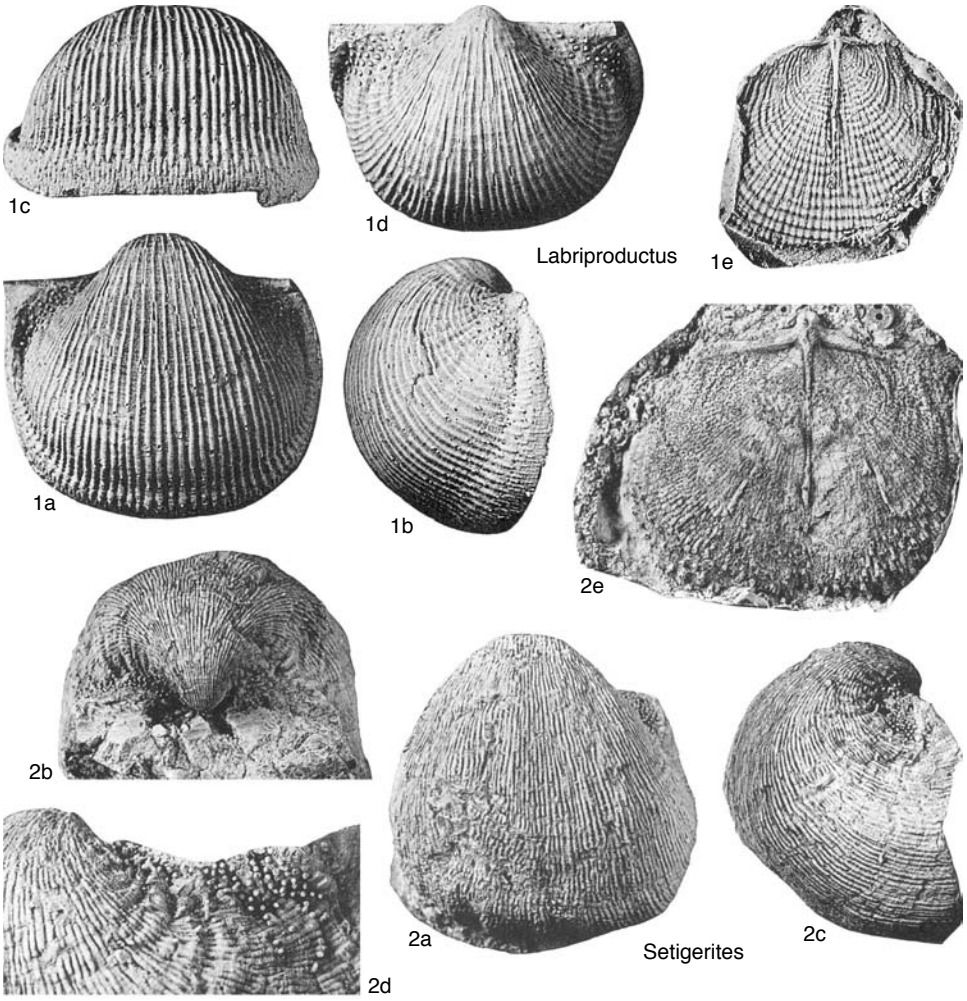

FIG. 341. Productidae (p. 500–501).

America, Europe.——FIG. 340,*1a–d. *M. marginicinctus* (PROUT), middle Viséan; *a,* ventral valve exterior, Missouri, ×1; *b,c,* oblique lateral, anterior views of specimen, Iowa, ×2; *d,* latex replica of dorsal valve interior, Tennessee, ×2 (Muir Wood & Cooper, 1960).——FIG. 340,*1e,f. M. projectus* (MUIR-WOOD), Viséan, Cork; *e,* dorsal valve exterior, ×1; *f,* ventral view of shell with flange, ×1 (Muir-Wood & Cooper, 1960).

Setigerites GIRTY, 1939, p. 141, *nom. nov. pro Setigerella* GIRTY, 1938b, p. 434, *non* EHRENBERG, 1872 [**Productus setigerus* HALL, 1858a, p. 638; =*P. setiger, nom. correct.* MUIR-WOOD & COOPER, 1960, p. 197; OD]. Size medium; trail commonly with gutter, rugae at umbonal flanks weak; ribbing fine, entire, associated with slightly swollen spine bases; spine groups posteriorly and on ears; cardinal process pit small, lateral ridges only slightly divergent from hinge, no marginal ridges. *Lower Carboniferous (upper Tournaisian–lower Serpukhovian):* North America, Eurasia, ?northern Africa.——FIG. 341,*2a–e. *S. setiger* (HALL), upper Tournaisian; *a–c,* ventral, posterior, lateral views of ventral valve, Indiana, ×1, *d,* posterolateral region showing spine bases on ears, Indiana, ×2; *e,* latex replica of dorsal valve interior, Missouri, ×2 (Muir-Wood & Cooper, 1960).

Tribe TOLMATCHOFFIINI Sarytcheva, 1963

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 928, *ex* Tolmatchoffiidae SARYTCHEVA in SARYTCHEVA & others, 1963, p. 168] [Spinifronsinae WATERHOUSE, 1981, p. 82]

Dorsal trail of varied length; ribbing covering both valves, other than in lower

Tournaisian, when umbos smooth; rugae commonly absent, spines on ventral valve not uniformly distributed; commonly with elongate cardinal process pit. *Lower Carboniferous (Tournaisian)–upper Lower Permian (Roadian).*

Tolmatchoffia Fredericks, 1933, p. 28 [**Productus robustus* Tolmatchoff, 1924, p. 230; OD]. Medium size; almost planoconvex, deep corpus, gently spreading trail; ribbing entire, becoming wider, indistinct on ventral trail; rugae more distinct dorsally, reticulate; spines scattered on both valves, commonly concentric on ventral trail; cardinal process large, normally with pit, cardinal ridges may reach ears, no marginal ridges. *Lower Carboniferous (upper Tournaisian):* Eurasia, northern Africa, North America.——Fig. 342*a–e.* **T. robusta* (Tolmatchoff), Tournaisian, Kuzbass, central Asia; *a–c,* neotype, selected by Sarytcheva in Sarytcheva and others, 1963, ventral, lateral, posterior views of ventral valve, PIN 1493/149, ×1; *d,* dorsal valve exterior, ×1; *e,* dorsal valve interior, ×1 (Sarytcheva & others, 1963).

Acanthocosta Roberts, 1971, p. 104 [**A. teicherti;* OD]. Small to medium size, 20 to 25 mm wide; ribbing absent at beak, elongate spine bases posteriorly becoming regular ribs anteriorly with spines, thicker spines in rows on flanks, few and fine dorsally; cardinal ridges short. *Lower Carboniferous (Tournaisian):* Australia.——Fig. 343*a–f.* **A. teicherti,* Tournaisian, Bonaparte Gulf, Australia; *a–d,* holotype, ventral, lateral, posterior, anterior views, CPC 8645, ×2; *e,f,* interior, exterior views of dorsal valve showing spine bases, ×4 (Roberts, 1971).

Brasilioproductus Mendes, 1959, p. 48 [**Productus chandlessi* Derby, 1874, p. 51; OD]. Medium size; reticulate visceral disk, ribbing weak on trail; dorsal spines with row near hinge. *Upper Carboniferous (Bashkirian–Moscovian):* South America, southern North America.——Fig. 344,*1a–e.* **B. chandlessi* (Derby), Morrowan–Desmoinesian, Brazil; *a,b,* ventral, lateral views of complete specimen, ×1.7; *c,* dorsal view of complete specimen, ×1.3 (Mendes, 1959); *d,e,* ventral valve anterior view, dorsal valve interior, ×1 (Derby, 1874).

Libys Massa, Termier, & Termier, 1974, p. 175 [**L. hericinus;* OD]. Size reaches around 55 mm wide; resembles *Peniculauris,* but with dorsal spines restricted to margins and ears, not on hinge or umbo. *Lower Carboniferous (Viséan):* northern Africa.——Fig. 344,*2a.* **L. hericinus,* Holkerian, Libya; posterior view of ventral valve, ×1 (new).——Fig. 344,*2b–e. L. minor* Massa, Termier, & Termier, Viséan, Libya; *b–d,* holotype, ventral, dorsal, lateral views, TA 92/6, ×1; *e,* dorsal view of internal mold, ×1 (new).

Marginatia Muir-Wood & Cooper, 1960, p. 262 [**Productus fernglenensis* Weller, 1909, p. 299; OD] [=*Paramarginatia* Yang Shi-pu, 1978, p. 111 (type, *P. weinginensis;* OD)]. Small to medium size; reticulate posteriorly; dorsal spines rare, small; dorsal valve with variably positioned lateral ridges, commonly extending to lateral margins and commonly subperipheral rim. *Lower Carboniferous (lower Viséan):* North America, Europe, northern Africa, central China.——Fig. 344,*3a–d.* **M. fernglenensis* (Weller), lower Viséan, Missouri; *a–c,* posterior, anterior, lateral views of ventral valve, ×1; *d,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Peniculauris Muir-Wood & Cooper, 1960, p. 278 [**P. mckeei;* OD; *nom. nov. pro Productus ivesi* King, 1931, p. 69, *non* Newberry, 1861]. Medium to large, widest at hinge, with large ears; ginglymus incipient; ventral profile somewhat flattened posteriorly, geniculate and long trail; ribbing strong, swollen at densely positioned spine bases; disks weakly reticulate; spines in rows near hinge, clusters on ears and scattered over ventral valve, fine on dorsal valve; cardinal process trifid with large median sector; lateral ridges extend across ears; adductor scars wide; long median septum. *Lower Permian (Sakmarian–Roadian):* USA.——Fig. 345,*1a–e.* **P. mckeei,* Lower Permian, Leonard Formation, Texas; *a–d,* holotype, viewed ventrally, anteriorly, laterally, dorsally, USNM 123445, ×1; *e,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Piloricilla Carter, 1987, p. 33 [**P. desmetensis;* OD]. Resembles *Acanthocosta,* but with flared lateral margins and some thicker ventral spines anteriorly; cardinal ridges widening laterally and uniting with obscure marginal rim. *Lower Carboniferous (lower Viséan):* Canada.——Fig. 345,*2a–g.* **P. desmetensis,* lower Viséan, western Alberta; *a–e,* holotype, ventral, anterior, lateral, posterior, dorsal views, GSC 63246, ×1; *f,* dorsal valve interior, ×2; *g,* posterior view of preceding specimen, ×3 (Carter, 1987).

Scissicosta Lazarev in Lazarev & Suur'suren, 1992, p. 65 [*S. gobiensis;* OD]. Resembles *Tolmatchoffia,* but smaller, more concave dorsal valve, ribbing absent at beaks, well defined on trails; dorsal spines rare, confined to zone of geniculation. *lower Lower Carboniferous (lower Tournaisian):* Mongolia.——Fig. 346,*1a–d.* **S. gobiensis,* Hastarian, Mongolia; *a,b,* holotype, ventral, lateral views, PIN N 3385/1080, ×1; *c,* ventral valve exterior, ×1; *d,* incomplete dorsal valve interior, ×1 (Lazarev & Suur'suren, 1992).——Fig. 346,*1e. S. busalaensis* Suur'suren; exterior mold of dorsal valve, ×1 (Lazarev & Suur'suren, 1992).

Spinifrons Stehli, 1954, p. 318 [**S. quadratus;* OD]. Medium size, resembling *Peniculauris,* but with clusters of thicker spines on ears and rarely anteriorly; cardinal process small; weakly developed lateral ridges close to hinge, and other internal morphology weak. *Lower Permian (upper Sakmarian–Artinskian):* southern USA.——Fig. 346,*3a–e.* **S. quadratus,* Lower Permian, Bone Spring Formation, Texas; *a,b,* shell viewed ventrally, posteriorly, ×1; *c,* lateral view, ×1; *d,e,* dorsal valve exterior, interior, ×1 (Muir-Wood & Cooper, 1960).

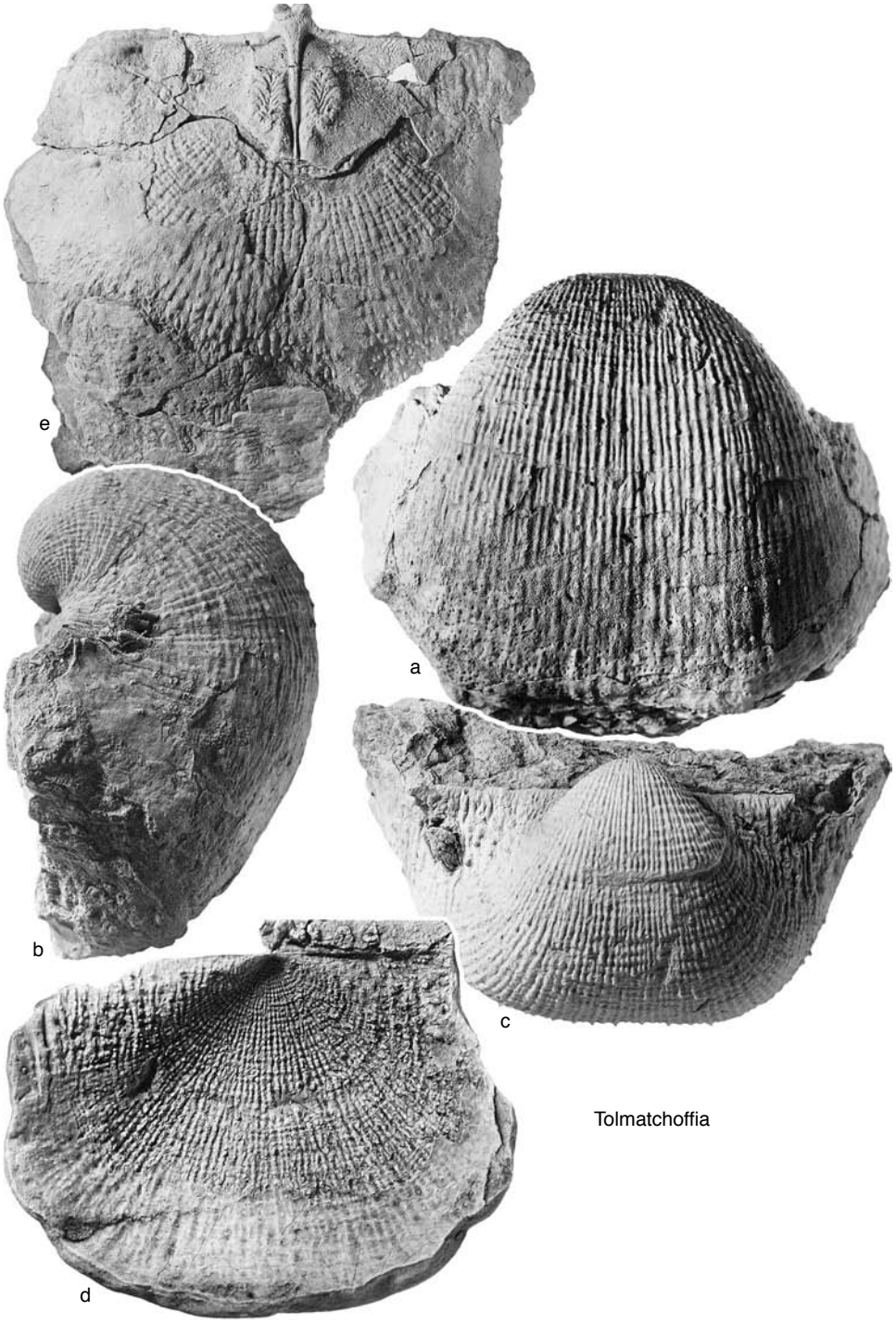

FIG. 342. Productidae (p. 502).

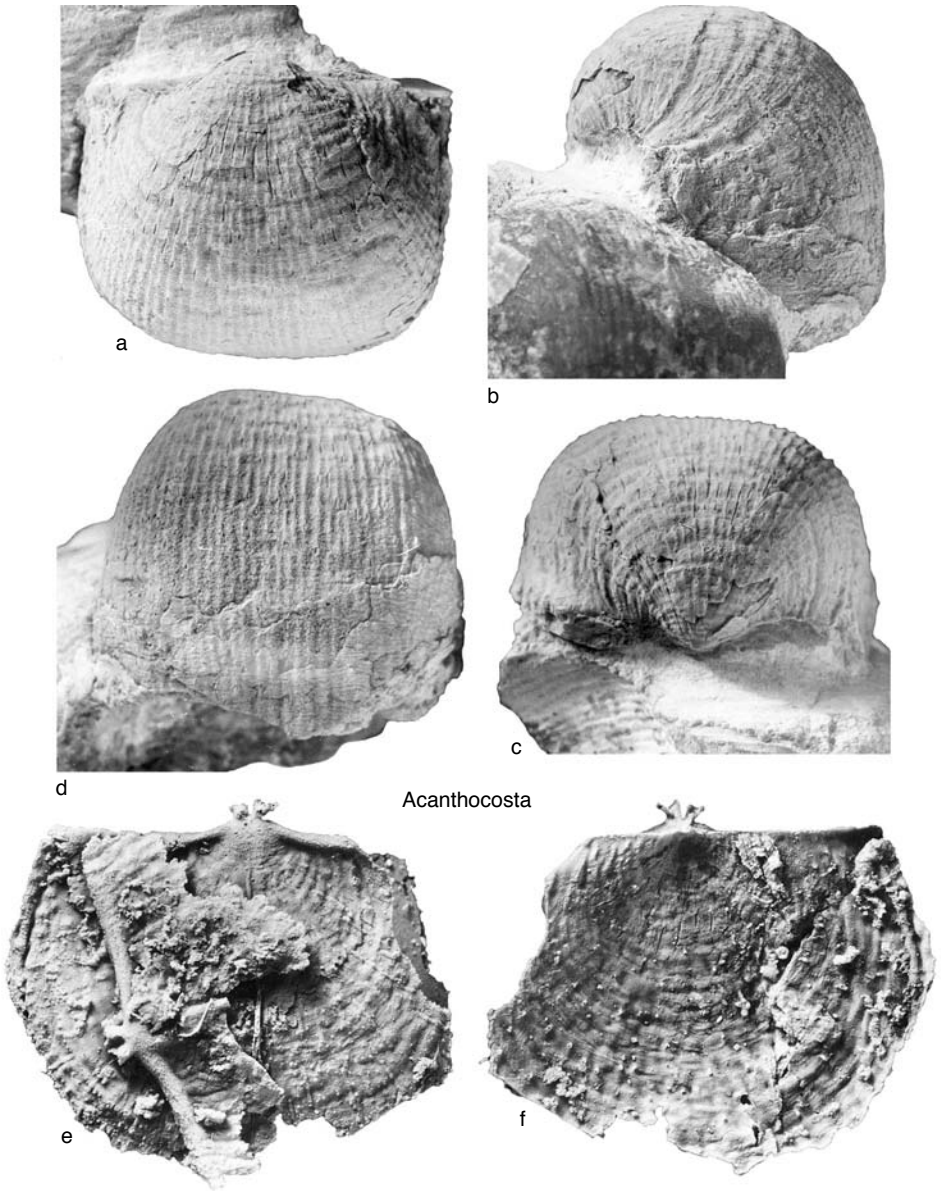

FIG. 343. Productidae (p. 502).

Squamaria MUIR-WOOD & COOPER, 1960, p. 287 [**S. moorei;* OD]. Medium size with wide hinge; ventral trail lamellose marginally; disks reticulate, but ribbing weak, irregular on trails; spines in prominent thick clusters on ears of both valves, widely scattered ventrally on accentuated ribs, sparse, fine dorsally; lateral, marginal ridges weak; shell substance thick. *Lower Permian:* USA.——FIG. 347,*1a–f.* **S. moorei,* Lower Permian, Talpa Formation, Texas; *a,b,* holotype, viewed anteriorly, dorsally, USNM 123987, ×1; *c,d,* posterior, lateral views of shell, ×1; *e,* incomplete ventral valve interior, ×1; *f,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Tomilia SARYTCHEVA in SARYTCHEVA & others, 1963, p. 220 [**T. khalfini;* OD]. Resembles *Tolmatchoffia,* but smaller, ribbing less well developed, sulcate, with thick-walled valves; cardinal process massive, protruding, supported by thick, short, divergent lat-

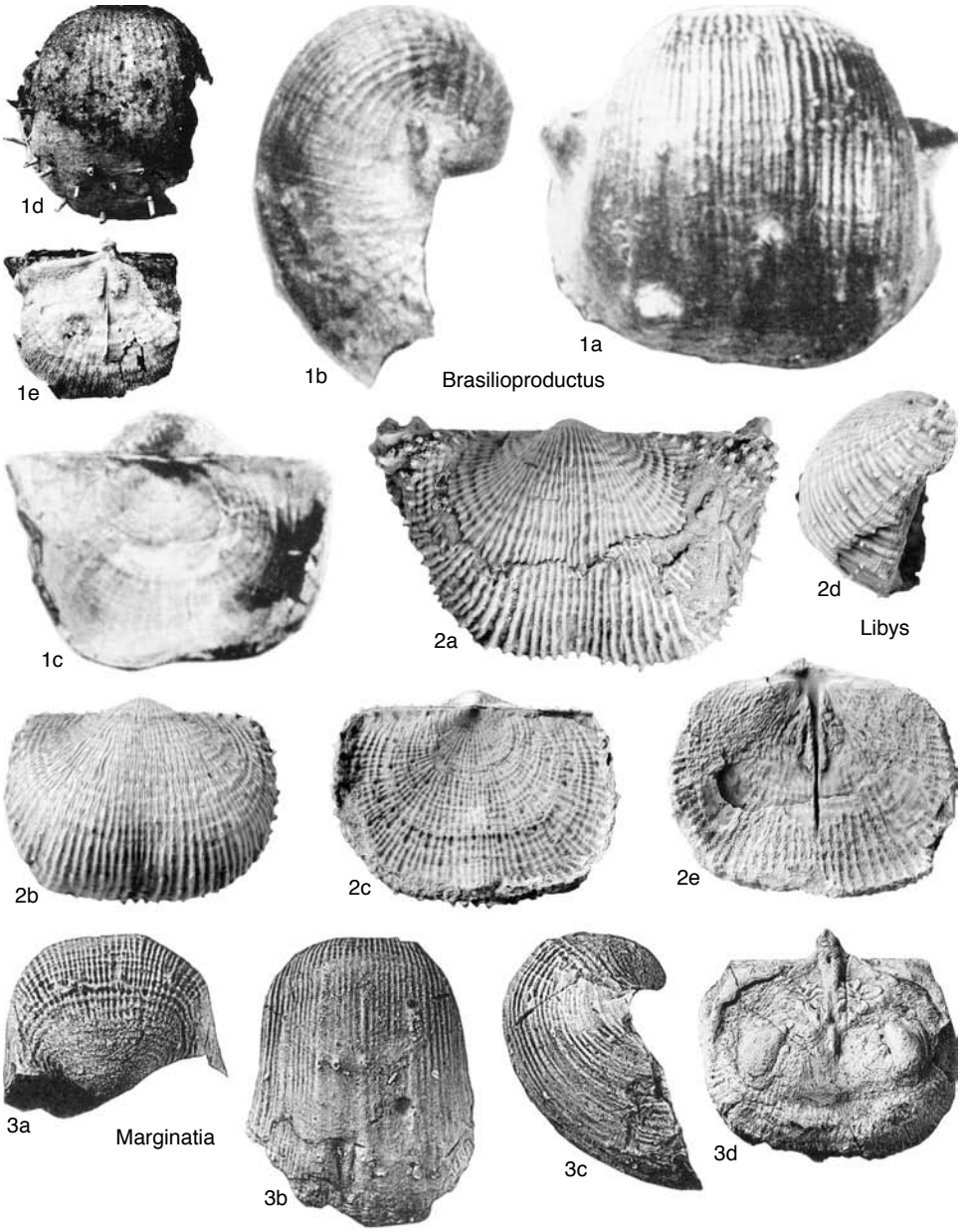

FIG. 344. Productidae (p. 502).

eral ridges. *Lower Carboniferous (lower Viséan):* Siberia.——FIG. 346,*2a–e.* **T. khalfini,* Viséan, Kuzbass, central Asia; *a,b,* ventral, posterior views of ventral valve, ×1; *c,* posterior view of ventral valve internal mold, ×1; *d,e,* holotype, lateral, dorsal views of internal mold, PIN N 1493/134, ×1 (Sarytcheva & others, 1963).

Tomiproductus SARYTCHEVA in SARYTCHEVA & others, 1963, p. 201 [**Productus elegantulus* TOLMATCHOFF, 1924, p. 244; OD]. Small; thin shelled, deep corpus, elongate ventral trail; ribbing entire, fine, weak reticulation on disks; spines sparsely scattered, thicker, somewhat concentric on ventral trail; paired ridges posterior to dorsal adductor scars, lateral

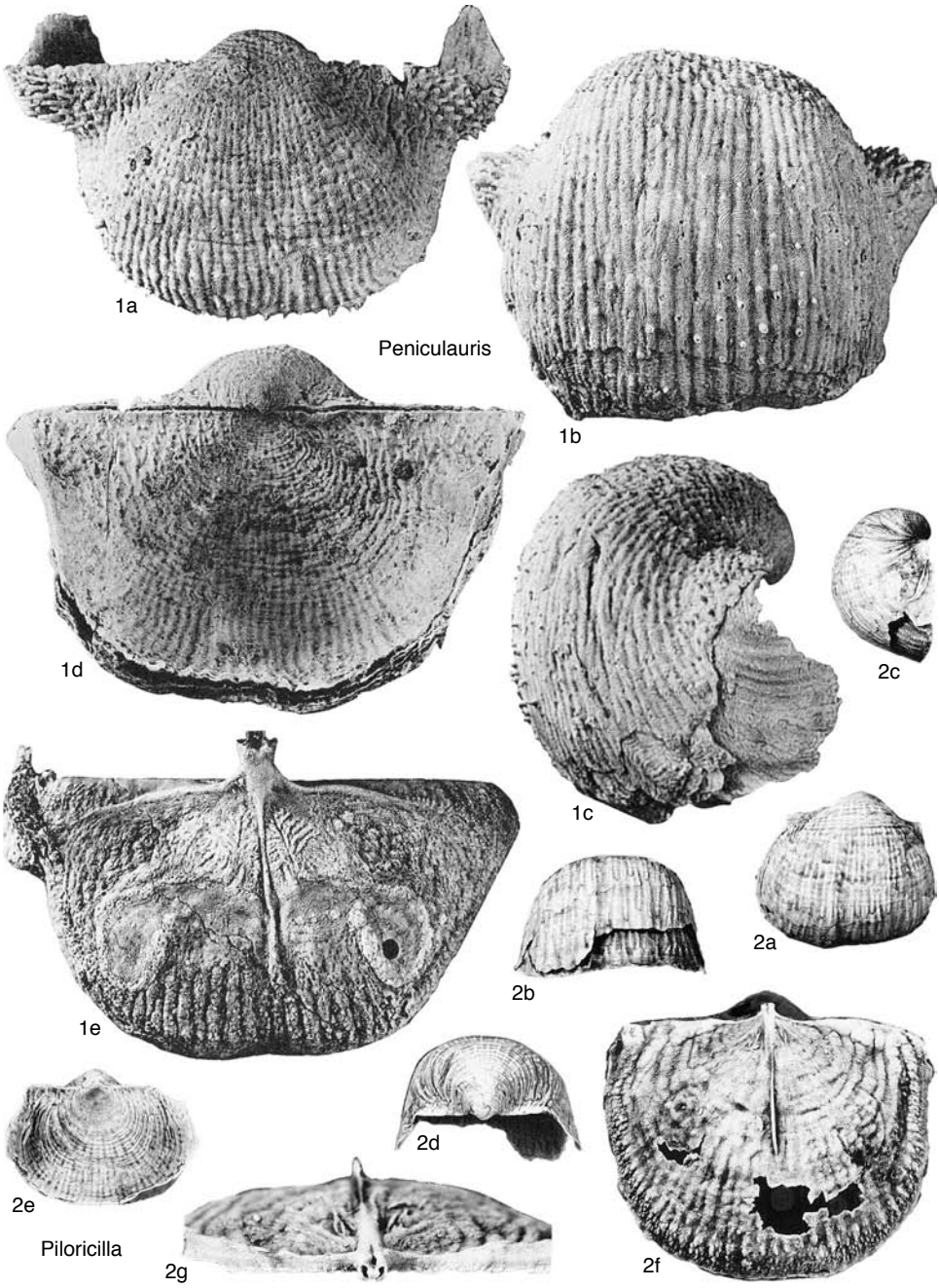

FIG. 345. Productidae (p. 502).

ridges reach ears. *Lower Carboniferous (lower Tournaisian):* Eurasia, North America, ?northern Africa.——FIG. 348,*2a–e.* **T. elegantulus* (TOLMATCHOFF), Tournaisian, Kuzbass, central Asia; *a–c,* neotype, dorsal, lateral, anterior views, PIN N 1493/238, ×1; *d,* posterior view of ventral valve,

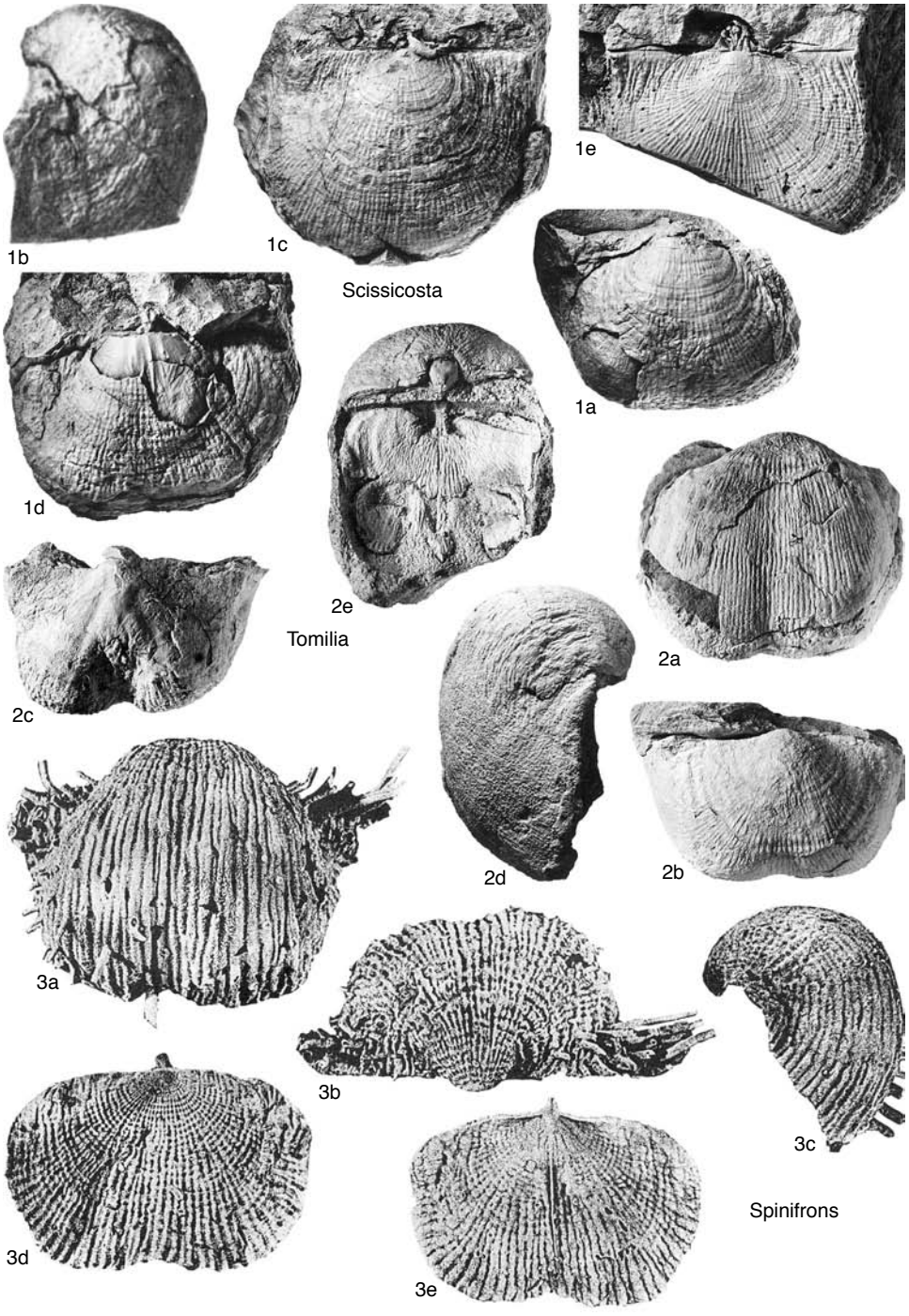

FIG. 346. Productidae (p. 502–505).

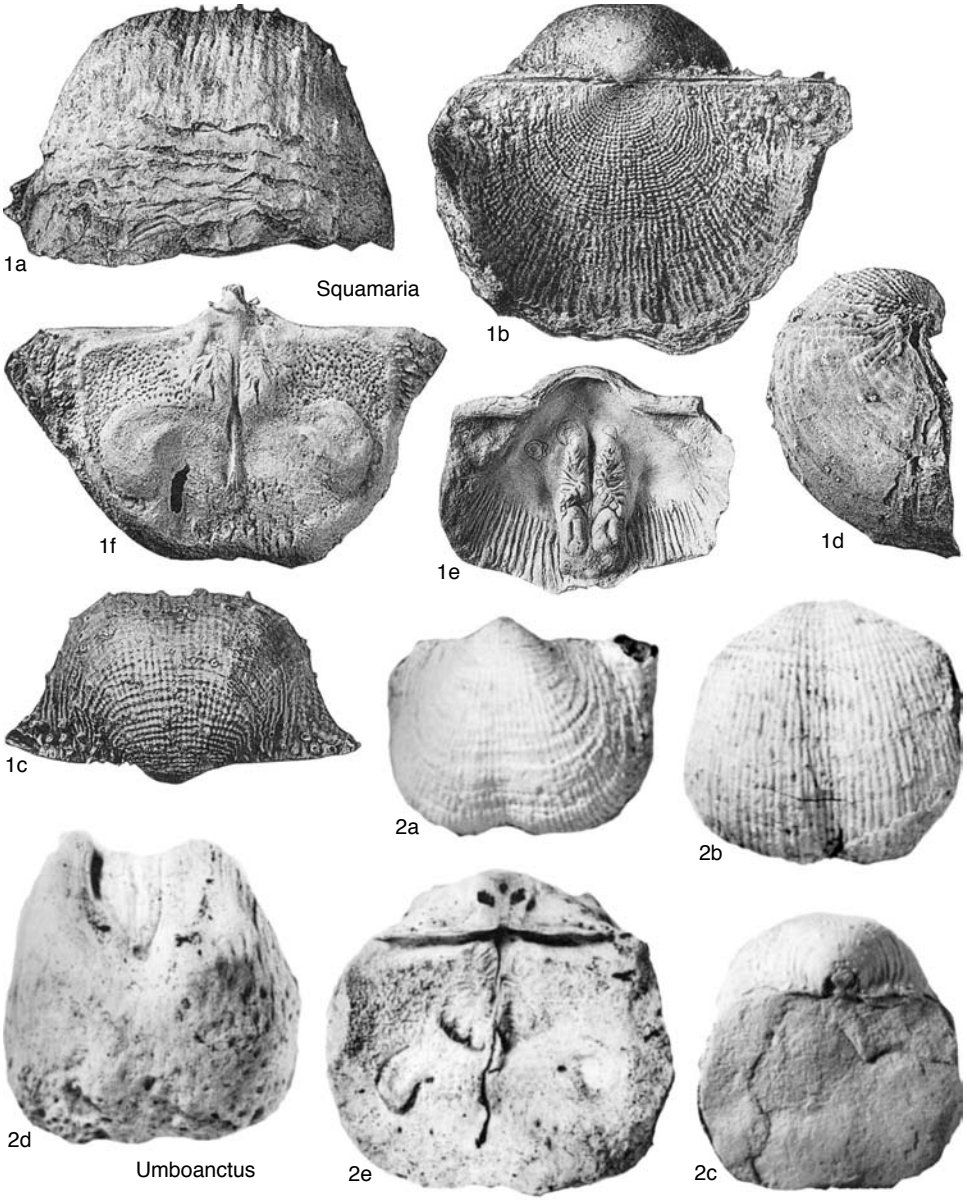

FIG. 347. Productidae (p. 504–508).

×1; *e,* dorsal valve interior, ×3 (Sarytcheva & others, 1963).

Umboanctus WATERHOUSE in BAMBER & WATERHOUSE, 1971, p. 212 [**U. spinosus;* OD]. Size medium; thick shelled with geniculated dorsal valve; ventral trail medianly sulcate, ribbing strong, clearly reticulate disks; spines numerous on both valves, concentric on ventral trail; cardinal ridges prominent, endospines large anteriorly; prominent ventral adductor scar platform. *Upper Carboniferous (lower Moscovian):* Canada.——FIG. 347,*2a–e.* **U. spinosus,* Moscovian, Yukon; *a,* ventral view of ventral valve, ×1; *b,c,* holotype, anterior, dorsal views, GSC 26411, ×1; *d,e,* ventral, dorsal views of internal cast, ×1 (Bamber & Waterhouse, 1971).

Xinshaoproductus TAN ZHEN-XIU, 1986, p. 433[442] [**X. xinshaoensis;* OD] [=*Neoyanguania* SHI XIAO-YING, 1988, p. 348[352] (type, *N. quadrata*)]. Simi-

lar to *Marginatia,* but with less well-defined ribbing, reticulation posteriorly; spines numerous from ventral elongate bases, not known dorsally; weak cardinal ridges plus ridges posterolaterally to adductor scars. *Lower Carboniferous (upper Tournaisian):* southern China.——FIG. 348,*1a–d.* **X. xinshaoensis,* Tournaisian, Hunan; *a–c,* holotype, lateral, anterior, posterior views, HB 302, ×1; *d,* dorsal valve interior, ×1 (Tan, 1986).

Superfamily ECHINOCONCHOIDEA Stehli, 1954

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 928, *ex* Echinoconchidae STEHLI, 1954, p. 326]

Productidines widest anterior to hinge, with corpus cavity deep in most families; trail commonly very short; spines covering both valves, including at hinge, commonly arranged in concentric bands, recumbent, forming dense mats; ribbing absent. *Middle Devonian (Givetian)–Upper Permian (Changhsingian).*

Family ECHINOCONCHIDAE Stehli, 1954

[Echinoconchidae STEHLI, 1954, p. 326]

Corpus with planoconvex profile, cavity deep; dorsal trail commonly short; spines thin, commonly in concentric bands, recumbent. *Lower Carboniferous (Tournaisian)–Upper Permian (Kazanian).*

Subfamily ECHINOCONCHINAE Stehli, 1954

[*nom. transl.* MUIR-WOOD & COOPER, 1960, p. 243, *ex* Echinoconchidae STEHLI, 1954, p. 326]

Concentric bands well developed on both valves bearing spines differentiated in size; buttress plates, cardinal process pit absent. *Lower Carboniferous (upper Viséan)–Upper Permian (Kazanian).*

Tribe ECHINOCONCHINI Stehli, 1954

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 929, *ex* Echinoconchidae STEHLI, 1954, p. 326]

Medium to large; concentric bands cuesta-like in profile, posterior part smooth, narrower than anteriorly where spines differentiated by size; one or two rows of thicker spines posteriorly, thinner rows anteriorly; dorsal adductor scars tend to become raised, crests curve laterally. *Lower Carboniferous (upper Viséan)–Lower Permian (Sakmarian).*

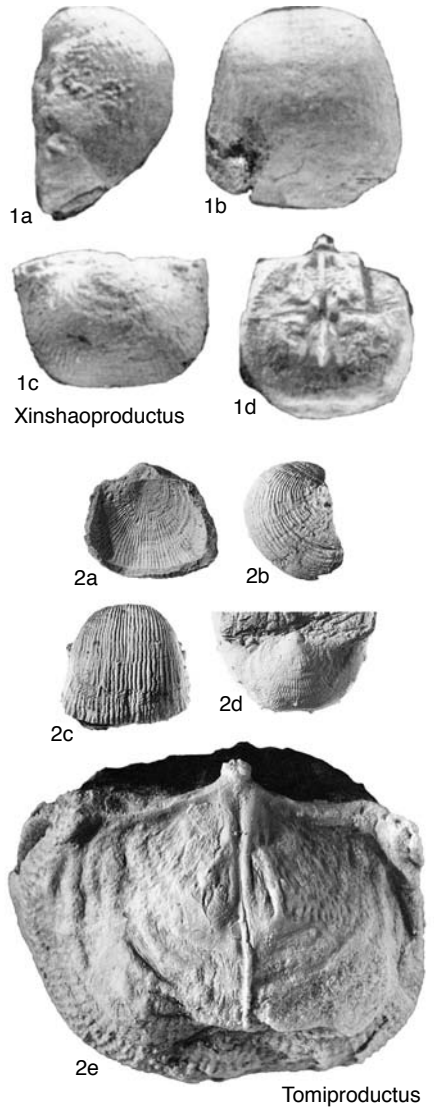

FIG. 348. Productidae (p. 505–509).

Echinoconchus WELLER, 1914, p. 138 [**Anomites punctatus* MARTIN, 1809, pl. 37, fig. 6–8, declared invalid from 1948, ICZN, 1950; =*Productus punctatus* J. SOWERBY, 1822 in 1821–1822, p. 22; SD CHAO, 1927b, p. 63]. Outline transversely subcircular, dorsal valve weakly concave, minimal trails; cardinal process narrow, supported by cardinal ridges; adductor scars elongate, slightly raised

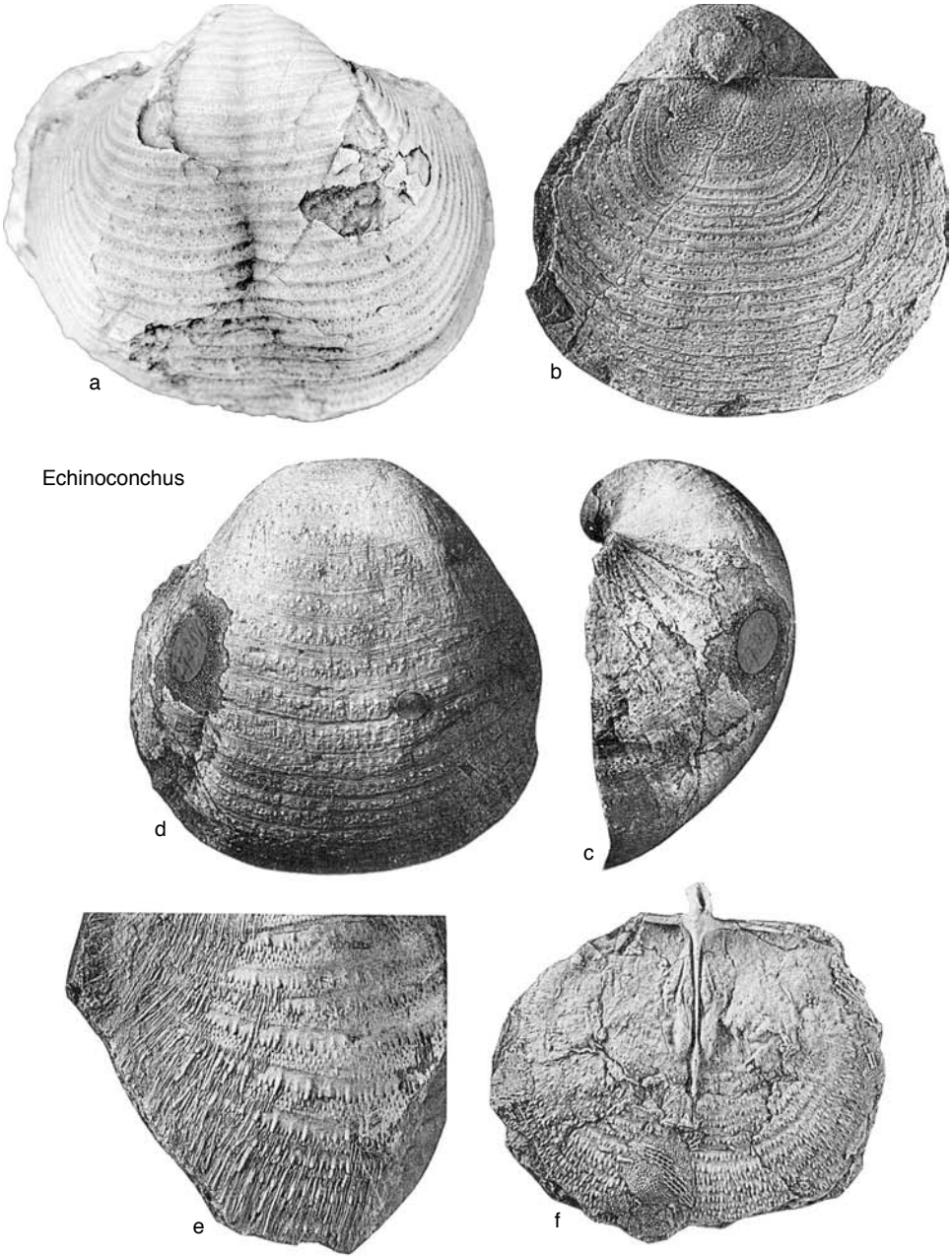

FIG. 349. Echinoconchidae (p. 509–510).

anteriorly. *Lower Carboniferous (upper Viséan):* cosmopolitan.——FIG. 349*a–e.* **E. punctatus* (J. SOWERBY), Asbian; *a,* lectotype, viewed ventrally, Derbyshire, British Isles, BMNH B 60966, ×1 (new); *b–d,* shell viewed dorsally, laterally, ventrally, Yorkshire, ×1; *e,* anterolateral detail of ventral exterior, Yorkshire, ×2 (Muir-Wood & Cooper, 1960).——FIG. 349*f.* **E. alternatus* (NORWOOD & PRATTEN), dorsal valve interior, Chesterian, Oklahoma, ×1 (Muir-Wood & Cooper, 1960).

Echinaria MUIR-WOOD & COOPER, 1960, p. 248 [**Productus semipunctatus* SHEPARD, 1838, p. 153; OD].

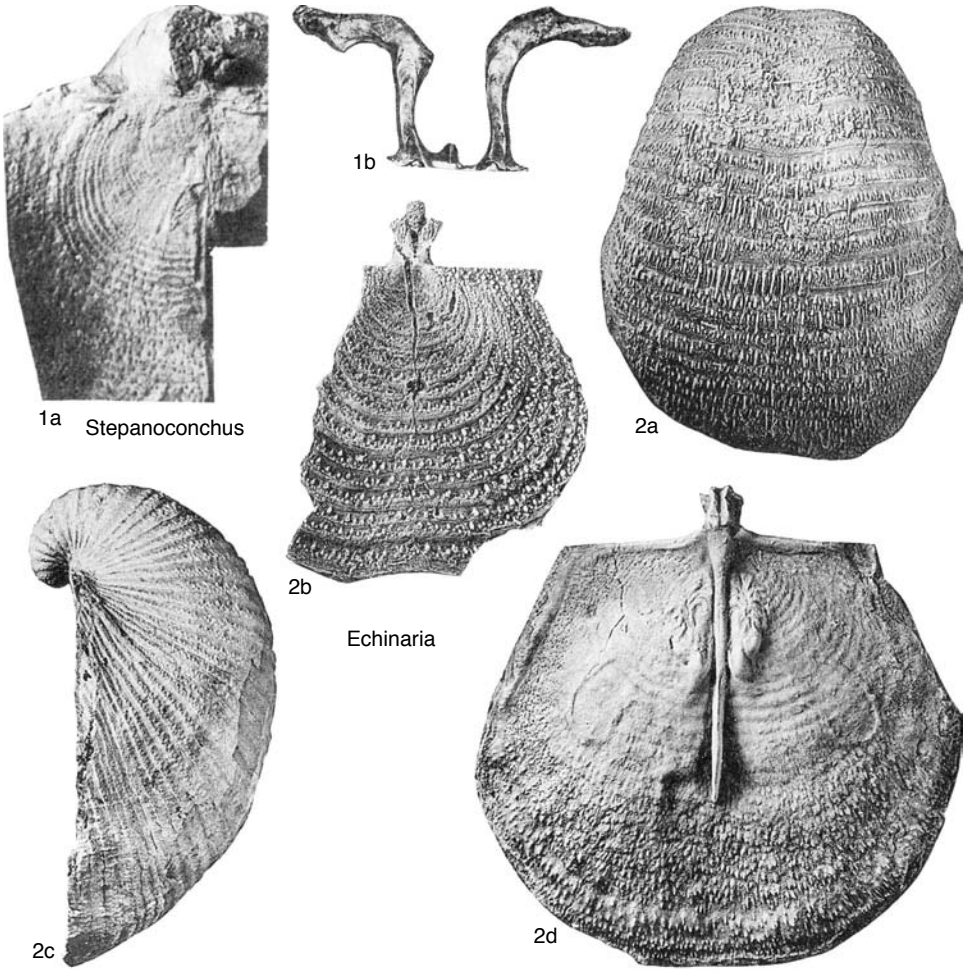

FIG. 350. Echinoconchidae (p. 510–511).

Medium to large; elongate outline widening anteriorly; cardinal ridges, strong median septum support narrow, trifid, cardinal process; ear baffles weak. *Upper Carboniferous (Gzhelian)–Lower Permian:* North America, northern South America, Eurasia.——FIG. 350,*2a–d. *E. semipunctata* (SHEPARD), Virgilian; *a,* ventral valve exterior, Texas, ×1; *b,* incomplete dorsal valve exterior, Texas, ×2; *c,* shell viewed laterally, Kansas, ×1; *d,* dorsal valve interior, Illinois, ×1 (Muir-Wood & Cooper, 1960).

Stepanoconchus LAZAREV, 1985, p. 69[68] [**Echinoconchus postpunctatus* STEPANOV in VOLGIN, 1960, p. 62; OD]. Externally resembles *Echinoconchus,* but differs internally by having dorsal adductor scars on laterally curving muscle platforms. *upper Upper Carboniferous (upper Gzhelian)–Lower Permian (Sakmarian):* Ural Mountains.——FIG. 350,*1a,b. *S. postpunctatus* (STEPANOV), Lower Permian, Ural Mountains; *a,* dorsal view of incomplete shell fractured at adductor platform, ×0.75; *b,* transverse section of dorsal adductor platform, valve internal surface to bottom, ×5 (Lazarev, 1990).

Tribe CALLIPROTONIINI Lazarev, 1985

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 929, *ex* Calliprotoniinae LAZAREV, 1985, p. 71]

Medium size; concentric ornamentation of low, anteriorly, somewhat lamellose bands covered by evenly distributed recumbent spines on each band, grading from large to small anteriorly; lateral ridges strongly developed, extending as submarginal ridges. *Upper Carboniferous (Gzhelian)–Lower Permian (Sakmarian).*

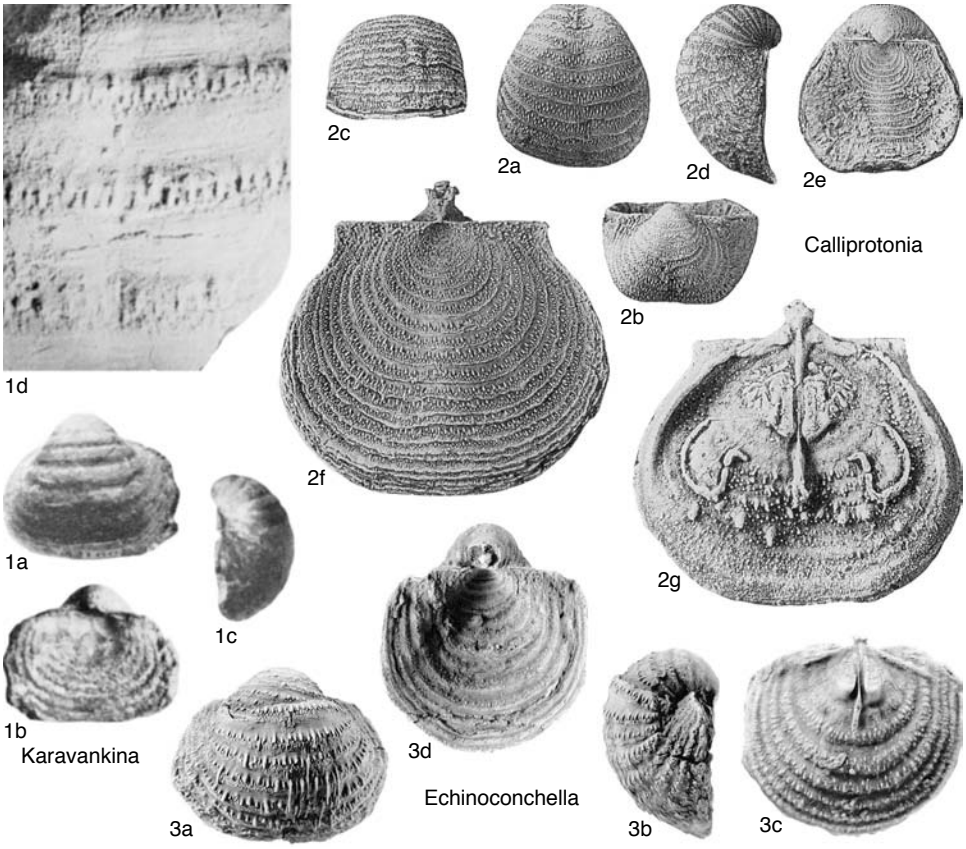

FIG. 351. Echinoconchidae (p. 512).

Calliprotonia MUIR-WOOD & COOPER, 1960, p. 246 [**C. renfrarum;* OD]. Small to medium size; planoconvex with short trails, commonly weak ventromedian sulcation; cardinal process trifid, strongly supported by lateral ridges. *Upper Carboniferous (Gzhelian)–Lower Permian (Sakmarian):* North America, South America, eastern Europe (Moscow basin, Ural Mountains), Asia, ?Spitzbergen.——FIG. 351,*2a–g. *C. renfrarum,* Virgilian, Texas; *a–e,* shell viewed ventrally, posteriorly, anteriorly, laterally, dorsally, ×1; *f,g,* dorsal valve exterior, interior, ×2 (Muir-Wood & Cooper, 1960).

Tribe KARAVANKININI Ramovš, 1969

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 929, *ex* Karavankininae RAMOVŠ, 1969, p. 261]

Small to medium size; high relief concentric bands, symmetrical in profile, tops bearing concentric rows of spines, distributed by size, separated by wider smooth bands; dorsal adductor scars raised, crests curved medianly after Serpukhovian. *Lower Carboniferous (Brigantian)–Upper Permian (Kazanian).*

Karavankina RAMOVŠ, 1969, p. 261 [**K. typica;* OD] [=*Karavankina* RAMOVŠ, 1966, p. 120, *nom. nud.*]. Small to medium size; outline commonly transversely subcircular; concentric bands with wide, spine-free regions; cardinal ridges weak, paired dorsal adductor platforms undercut anteromedianly. *Upper Carboniferous–Upper Permian (Kazanian):* Eurasia.——FIG. 351,*1a–d. *K. typica,* Kazanian, northern Yugoslavia; *a–c,* holotype, viewed ventrally, dorsally, laterally, UL 3714/160, ×1; *d,* detail of ventral ornament, ×5 (Ramovš, 1969).

Echinoconchella LAZAREV, 1985, p. 70[68] [**Productus elegans* M'COY, 1844, p. 108; OD]. Resembles *Karavankina,* but without dorsal muscle platforms. *Lower Carboniferous (Brigantian–lower Serpukhovian):* Eurasia.——FIG. 351,*3a–c. *E. elegans* (M'COY), Brigantian, Scotland; *a,b,* shell viewed ventrally, laterally, ×2; *c,* dorsal valve interior, ×3 (new).——FIG. 351,*3d. E. venusta* (THOMAS), lower Brigantian, Derbyshire; dorsal view of shell showing spine bases, ×2 (new).

Subfamily JURESANIINAE Muir-Wood & Cooper, 1960

[Juresaniinae Muir-Wood & Cooper, 1960, p. 266]

Concentric bands absent or confined anteriorly; spines may be differentiated by size anteriorly; cardinal process pit, buttress plates present in Carboniferous juveniles only. *Lower Carboniferous (Tournaisian)–Upper Permian (Kazanian).*

Tribe JURESANIINI Muir-Wood & Cooper, 1960

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 929, *ex* Juresaniinae Muir-Wood & Cooper, 1960, p. 266] [=Bathymyoniinae Lazarev, 1986c, p. 29]

Quincuncial pustules posteriorly, reducing in area through upper Permian; concentric bands of spines commonly on rest of valves; anteriorly rugose or lamellose. *Lower Carboniferous (upper Asbian)–upper Lower Permian (Roadian).*

Juresania Fredericks, 1928, p. 786 [**Productus juresanensis* Chernyschev, 1902, p. 276; OD]. Smaller medium size, subquadrate outline with hinge forming widest part; ventral profile weakly geniculate; median sulcation weak; ventral disk with elongate spine bases arranged quincuncially, anterior to disk (trail) nonrugose bands with differentiated spines, elongate thicker spines posteriorly, thinner recumbent spines anteriorly; buttress plates converge anteriorly to median septum. *upper Upper Carboniferous (Kasimovian)–Lower Permian (Asselian):* Arctic Eurasia, western Himalayas.——Fig. 352,*3a–e.* **J. juresanensis* (Tschernyschew), *Schwagerina* Limestone, Juresan River, Russia; *a,b,* syntype, specimen viewed posteriorly, laterally, ×1 (Muir-Wood & Cooper, 1960); *c,* anteroventral view of ventral valve, ×1; *d,* detail of ventral trail, ×3 (Lazarev, 1990); *e,* dorsoposterior view of shell with dorsal valve removed, showing short convergent buttress plates (*arrow*), ×3 (new).

Ametoria Cooper & Grant, 1975, p. 1055 [**A. residua;* OD]. Medium, hinge wide; spines of two sizes covering venter, clusters on ears and flanks, finer covering dorsal valve; buttress plates absent. *upper Lower Permian (Roadian):* USA.——Fig. 352,*1a–e.* **A. residua,* Road Canyon Formation, Texas; *a–c,* holotype, viewed ventrally, anteriorly, laterally, USNM 153476, ×1; *d,* incomplete dorsal valve exterior, ×1; *e,* incomplete dorsal valve interior, ×1.5 (Cooper & Grant, 1975).

Bathymyonia Muir-Wood & Cooper, 1960, p. 244 [**Productus nevadensis* Meek, 1877, p. 64; OD]. Medium, subquadrate in dorsal outline; dorsal disk plane to gently concave with short trail; medium sulcation slight; spines mixed in size, varied inclinations; ventral disk with elongate swollen bases, anteriorly spines arranged in bands of several rows; cardinal process large, with shaft, buttress plates absent; cardinal ridges strong; ventral valve thick shelled posteriorly. *Lower Permian (?Artinskian, Kungurian):* USA, ?eastern China, ?Japan.——Fig. 353,*1a–g.* **B. nevadensis* (Meek), Lower Permian, Phosphoria Formation; *a–d,* lectotype, viewed ventrally, posteriorly, anteriorly, laterally, Nevada, USNM 668a, ×1; *e,* dorsal valve exterior, Nevada, ×1; *f,* ventral valve internal mold, Nevada, ×1; *g,* dorsal valve interior, Wyoming, ×1 (Muir-Wood & Cooper, 1960).

Bilotina Reed, 1944, p. 109 [**Strophalosia (Bilotina) subtecta;* OD] [=*Septasteges* Waterhouse & Piyasin, 1970, p. 120 (type, *S. acanthus;* OD)]. Smaller medium size with subquadrate corpus outline, deep planoconvex profile with geniculate trails; small cicatrix may be present; ventral ginglymus; elongate spine ridges may simulate impersistent ribbing; spines strong, evenly scattered on ventral valve, thin on dorsal valve; cardinal process strong, supported by paired elevated adductor platforms; cardinal, marginal ridges strong. *Lower Permian (Artinskian):* western Pakistan, Thailand.——Fig. 352,*2a–c.* **B. subtecta,* Amb Formation, Khisor Range; *a,b,* ventral valve exterior viewed ventrally, laterally, ×1; *c,* incomplete dorsal valve interior, ×1 (Grant, 1976). ——Fig. 352,*2d–g. B. acantha* (Waterhouse & Piyasin), Rat Bui Limestone, southern Thailand; *d,e,* ventral valve viewed ventrally, posteriorly; ×2; *f,* dorsal valve exterior, ×1; *g,* dorsal valve interior, ×2 (Grant, 1976).

Buntoxia Lazarev, 1986b, p. 94 [**Buxtonia scabricula* var. *mosquensis* Ivanov, 1935, p. 102; OD]. Dorsal valve almost flat; ventral spine bases swollen umbonally, rugae anteriorly with bands of differentiated spines; median septum grooved posteriorly. *upper Lower Carboniferous (upper Asbian)–Upper Carboniferous (Gzhelian):* Russia.——Fig. 354*a–d.* **B. mosquensis* (Ivanov), Moscovian, Myachkovian, Moscow basin; *a–c,* ventral valve exterior viewed anteroventrally, laterally, posteroventrally, ×1; *d,* dorsal valve interior, ×1 (new).——Fig. 354*e. B.* sp. aff. *B. mosquensis* (Ivanov), Kasimovian; detail of ventral ornament anteriorly, ×3 (Lazarev, 1990). ——Fig. 354*f. B.* sp., Serpukhovian; detail of ventral valve posteroventrally, ×3 (Lazarev, 1990).

Cubacula Lazarev, 1984, p. 73[70] [**Productus subpunctatus* Nikitin, 1890, p. 58; OD]. Small to medium sized; slightly emarginate outline; resembles *Parajuresania,* but between every four or five recumbent spines erect spines project from middle of bands, each widely separated by narrow rugae originating at about half corpus length, commonly symmetrical in profile. *Upper Carboniferous (Kasimovian–lower Gzhelian):* eastern Europe.——Fig. 355,*1a–f.* **C. subpunctata* (Nikitin), Kasimovian, Moscow basin; *a–c,* shell viewed ventrally, laterally, dorsally, ×1; *d,* detail of cardinal process dorsally, ×4; *e,* detail of ventral valve ornament, ×3; *f,* dorsal valve interior, ×1 (new).

Densepustula Lazarev, 1982, p. 66[66] [**Flexaria russiensis* Semenova, 1972, p. 26; OD]. Ornament

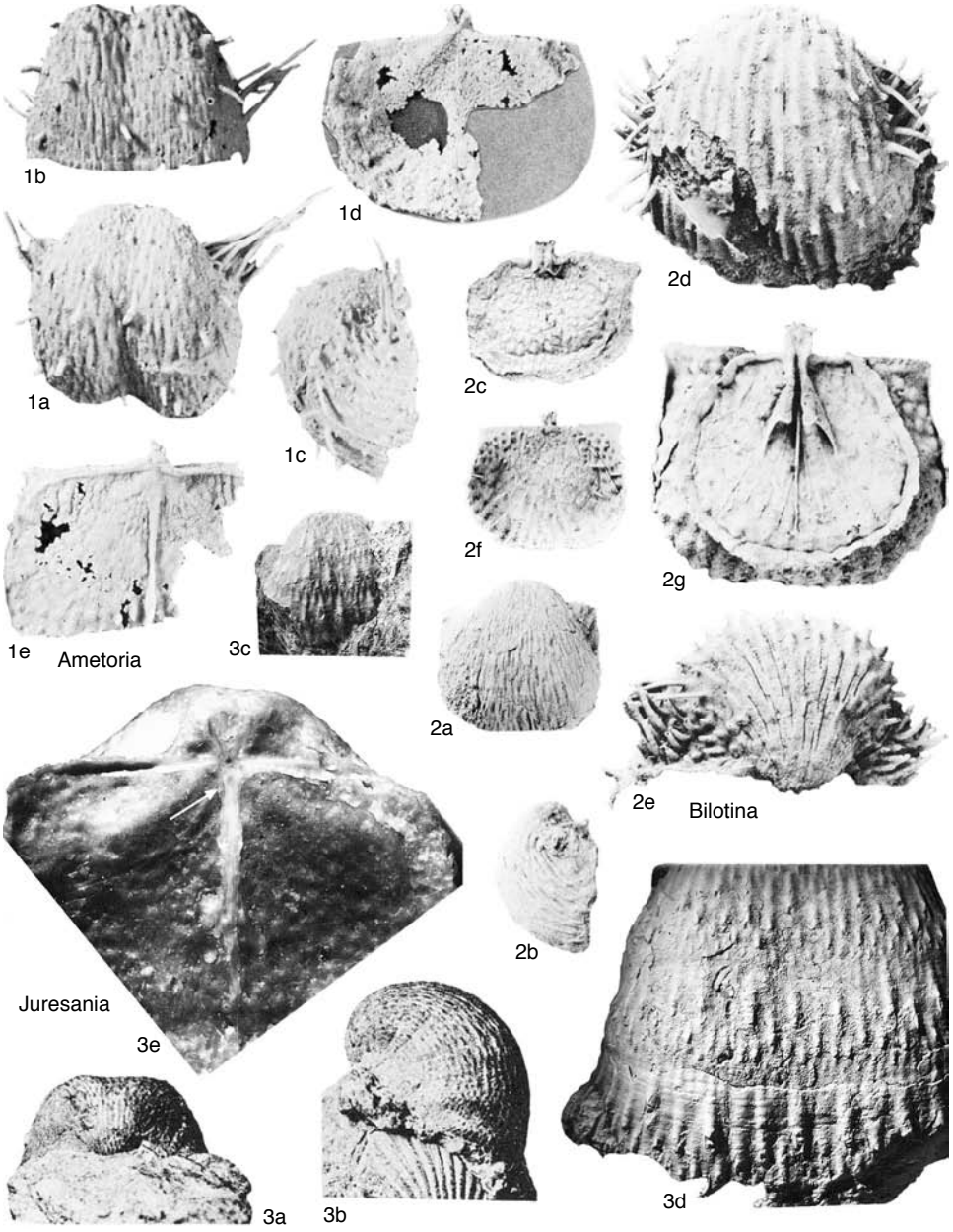

FIG. 352. Echinoconchidae (p. 513).

as in *Juresania* posteriorly, but lacks concentric bands anteriorly. *Upper Carboniferous (upper Bashkirian–lower Moscovian):* Russia.——FIG. 356,*1a–d.* **D. russiensis* (SEMENOVA), lower Moscovian, Moscow basin; *a,* ventral valve viewed anteriorly, ×3; *b,* dorsal valve exterior, ×1; *c,* detail of dorsal valve exterior, ×4; *d,* incomplete juvenile dorsal valve interior showing buttress plates, ×3 (Lazarev, 1982).

Parajuresania LAZAREV, 1982, p. 70 [**Productus nebrascensis* OWEN, 1852, p. 584; OD]. Resembles *Juresania* but differs in having small, uncommon ventral cicatrix; concentric bands with differentiated spines only anteriorly, anterior spines thin, recum-

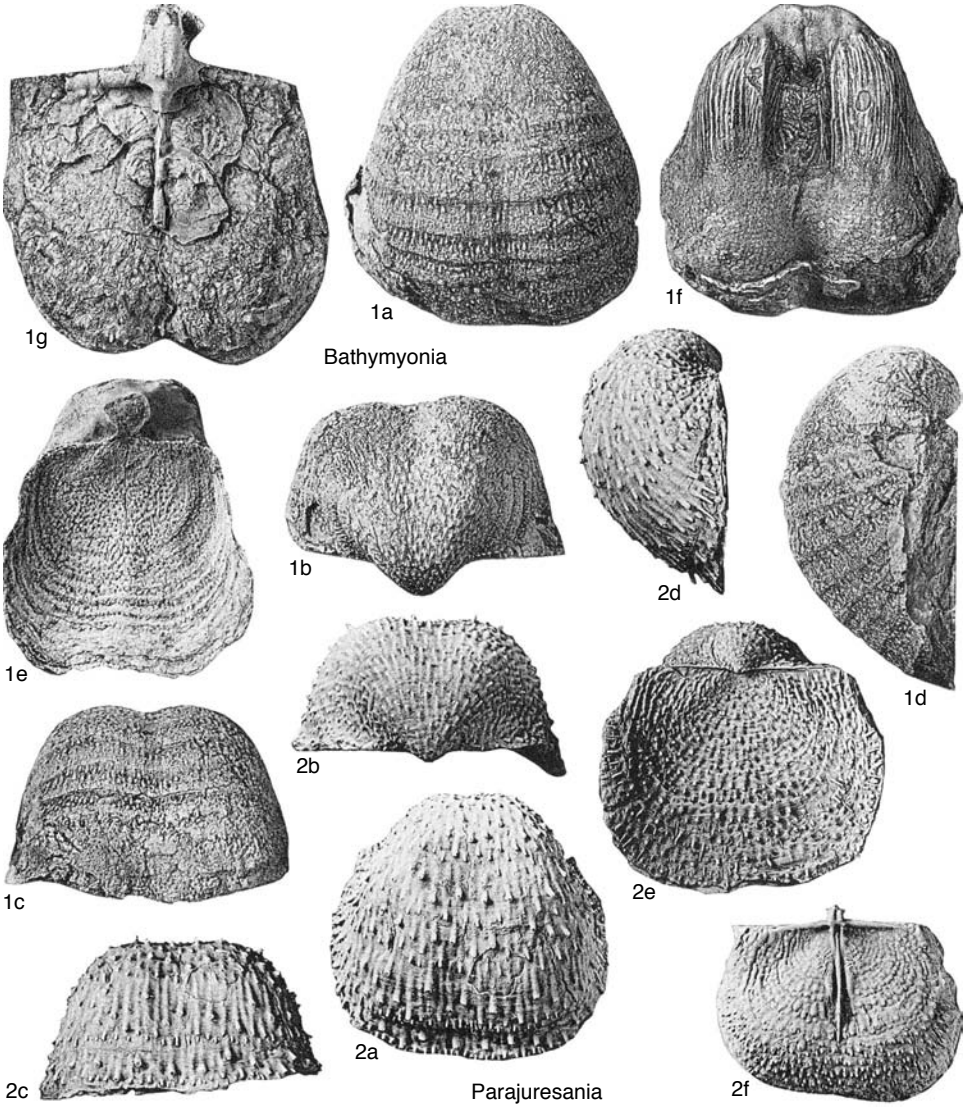

FIG. 353. Echinoconchidae (p. 513–515).

bent, posterior spines thicker, suberect; buttress plates subparallel as juvenile. *Upper Carboniferous (upper Kasimovian)–Lower Permian (Asselian):* North America, northern Europe.——FIG. 353,*2a–f. *P. nebrascensis* (OWEN), Asselian, Kansas; *a–e,* shell viewed ventrally, posteriorly, anteriorly, laterally, dorsally, ×1; *f,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Pulchratia MUIR-WOOD & COOPER, 1960, p. 249 [**Productus symmetricus* MCCHESNEY, 1860, p. 35; OD]. Resembles *Parajuresania,* but spines more uniform in size, lacking strong spine bases; lateral ridges diverge slightly from hinge, buttress plates weak, convergent, or lost in adults. *Upper Carboniferous (Kasimovian–Gzhelian):* North America.——FIG. 355,*2a–e. *P. symmetrica* (MCCHESNEY), Virgilian, Texas; *a–d,* shell viewed anteroventrally, laterally, dorsally, dorsolaterally, ×1 (new); *e,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Vediproductus SARYTCHEVA in SARYTCHEVA & SOKOLSKAYA, 1965, p. 219 [**V. vediensis;* OD]. Medium size, resembles *Juresania,* but differs by having spine bands of strong relief covering ventral valve; cardinal ridges bend sharply across ears. *upper Lower Permian (Roadian):* Transcaucasus, China.——FIG. 356,*2a–e. *V. vediensis,* Ufimian, Avush,

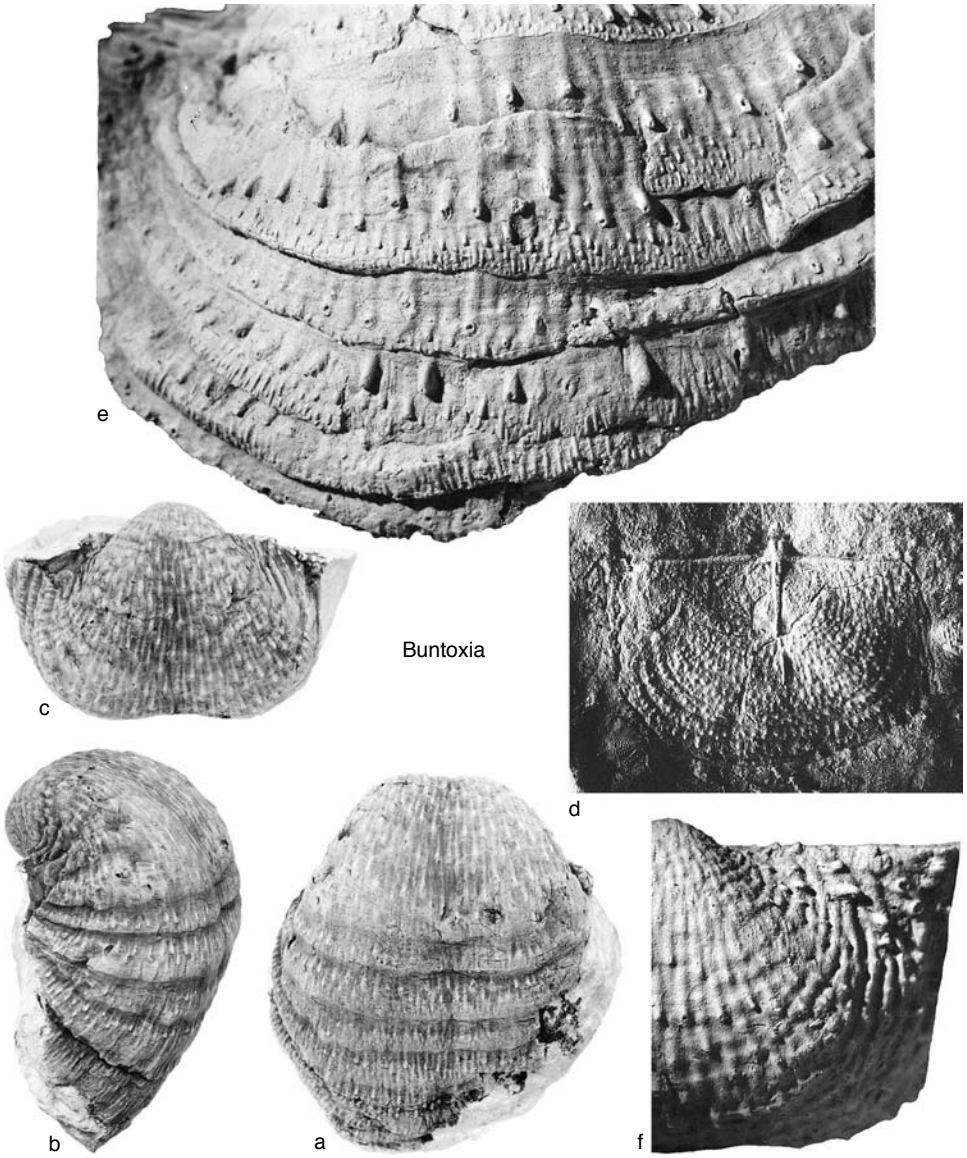

FIG. 354. Echinoconchidae (p. 513).

Transcaucasia; *a–c,* holotype, viewed ventrally, posteriorly, laterally, PIN 207/32, ×1; *d,* detail of ventral valve exterior, ×3; *e,* incomplete dorsal valve interior, ×1 (Sarytcheva & Sokolskaya, 1965).

Tribe WAAGENOCONCHINI Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 929, *ex* Waagenoconchinae MUIR-WOOD & COOPER, 1960, p. 252]

Corpus with small quincuncially arranged spines, dense mat of long peripheral spines; weak banding anteriorly; trails may be long. *Lower Carboniferous (Tournaisian)–Upper Permian.*

Waagenoconcha CHAO, 1927b, p. 24, 85 [**Productus humboldti* D'ORBIGNY, 1842, p. 54; OD] [=*Biplatyconcha* WATERHOUSE, 1983b, p. 125, *nom. nov. pro Platyconcha* WATERHOUSE, 1975, p. 8, *non* LONGSTAFF, 1933, gastropod (type, *P. grandis* WATERHOUSE, 1975, p. 8); *Ruthenia* FREDERIKS, 1928, p. 789 (type, *Productus irginae* STUCKENBERG, 1898, p. 340); *Wimanoconcha* WATERHOUSE, 1983b,

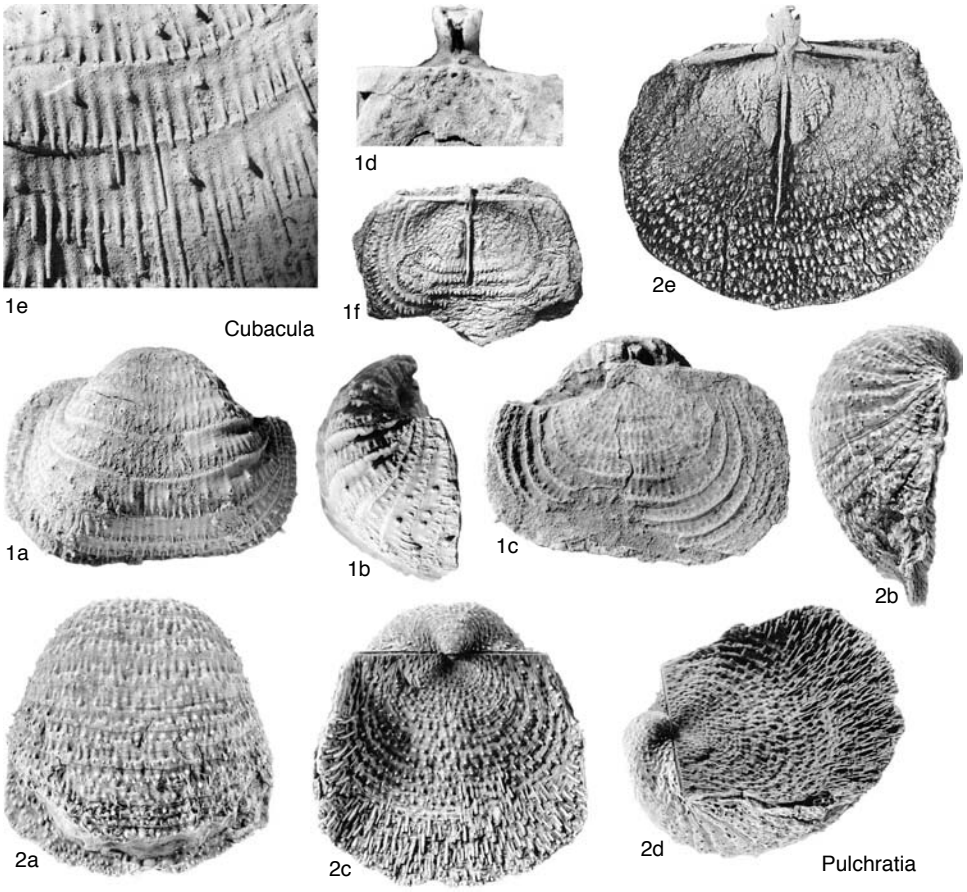

FIG. 355. Echinoconchidae (p. 513–515).

p. 125 (type, *Waagenoconcha wimani* FREDERIKS, 1934, p. 28)]. Medium to large shells; outline subrounded with hinge slightly less than maximum width; corpus planoconvex, with short trails; corpus covered by pustulose, slightly elongate spine bases arranged quincuncially; dorsal interior with no buttress plates. *Wimanoconcha* was reported as differing in having anteriorly thickened dorsal valve (but see ARCHBOLD, 1993, upper Capitanian of Australia). *Biplatyconcha* was reported as lacking dorsal spines. *upper Upper Carboniferous–Upper Permian:* cosmopolitan.

W. (**Waagenochocha**) CHAO, 1927b, p. 85 [**Productus humboldti* D'ORBIGNY, 1842, p. 54; OD]. *Waagenoconcha* with spreading flanks; ventral trail with smaller spines than corpus and with small rounded bases. *upper Upper Carboniferous–upper Lower Permian:* cosmopolitan.——FIG. 357,*1a–c.* **W. humboldti* (D'ORBIGNY), Lower Permian, Bolivia; shell viewed ventrally, dorsally, posteriorly, ×1 (Muir-Wood & Cooper, 1960).——FIG. 357,*1d. W. prophetica* (COOPER & GRANT), upper Finnis Shale, Gzhelian, Texas; detail of ventral valve exterior, ×2 (Muir-Wood & Cooper, 1960).——FIG. 357,*1e,f. W. magnifica* COOPER & GRANT, upper Lower Permian, Texas; dorsal valve exterior, part of interior, ×1 (Muir-Wood & Cooper, 1960).

W. (**Gruntoconcha**) ANGIOLINI, 1995, p. 206 [**W. (G.) macrotuberculata;* OD]. Differs from *Waagenoconcha* in having coarse, less elongate spine bases, weak differentiation of anterior nonswollen spine bases; weak rugae near start of ventral trail, steep lateral margins giving more strongly convex transverse profile. [*Septoproductus* FRECH, 1911, p. 132 (type, *Productus abichi* WAAGEN, 1884, p. 697) might be considered a senior synonym, but the type species was misidentified by FRECH and his genus belongs with *Tschernyschewia* STOYANOW, 1910; BRUNTON, 1997 (ICZN Case 3034)]. *upper Lower Permian (Roadian)–lower Upper Permian (Kazanian):* western Himalayas (Karakorum).——FIG. 357,*2a.* **W. (G.) macrotuberculata,* Ufimian, Karakorum; ventral valve exterior, ×1 (new).——FIG. 357,*2b–f. W. (G.) abichi*

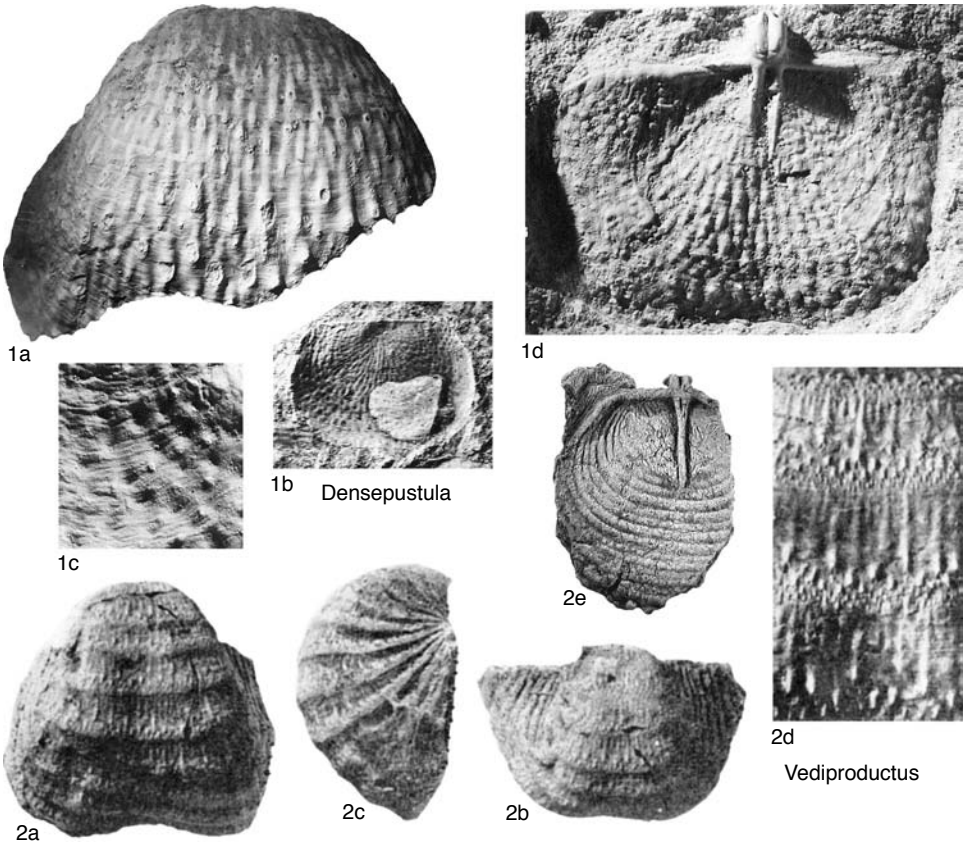

FIG. 356. Echinoconchidae (p. 513–516).

(WAAGEN), ?Kazanian, mid-*Productus* Limestone, Khisor Range; *b,c,* shell viewed ventrally, anteriorly, ×1 (Muir-Wood & Cooper, 1960); *d,* anteroventral view of shell, ×1.5; *e,* dorsal view of shell, ×1.25; *f,* dorsal valve interior, ×1.5 (Grant, 1966).

Balkhasheconcha LAZAREV, 1985, p. 68[66] [**Waagenoconcha balkhashensis* NASIKANOVA in SARYTCHEVA, 1968, p. 106; OD]. Similar to *Waagenoconcha* in ornament, but with buttress plates. *Upper Carboniferous (Bashkirian–Moscovian):* northeastern Arctic Russia.——FIG. 358,*2a–c. **B. balkhashensis* (NASIKANOVA), Upper Carboniferous, Keregetassk Formation, Kazakhstan; *a,* holotype, ventral valve exterior, PIN 1506/1163, ×1; *b,* incomplete dorsal valve interior, ×1; *c,* detail of ventral external ornament, ×3 (Sarytcheva, 1968).

Buxtoniella ABRAMOV & GRIGORJEVA, 1986, p. 94 [**B. longispina;* OD]. Similar to *Balkhasheconcha* but no anterior band of thinner spines on ventral valve. *Lower Carboniferous (middle Viséan):* Russia.——FIG. 358,*1a–d. *B. longispina,* middle Viséan, Sokolsk Beds, Verkhoyansk; *a,* holotype, anteroventral view of ventral valve, PIN 4002/858, ×1; *b,* ventral view of ventral exterior, ×1; *c,* dorsal view of incomplete specimen, ×1; *d,* incomplete dorsal valve interior, ×1 (Abramov & Grigorjeva, 1986).

Spinauris ROBERTS, 1971, p. 107 [**S. cristata;* OD]. Resembles *Waagenoconcha,* but lacks well-differentiated finer spines anteriorly; cardinal process shaft weak or lacking, pit variably present; cardinal ridges weak, short, may extend as weak ear baffles, submarginal ridge. *Lower Carboniferous (Tournaisian):* Western Australia.——FIG. 358,*3a–e. *S. cristata,* lower Tournaisian, Bonaparte Gulf; *a–d,* shell viewed ventrally, posteriorly, laterally, dorsally, ×1; *e,* holotype, dorsal valve interior, CPC 8543, ×1 (Roberts, 1971).

Subfamily PUSTULINAE Waterhouse, 1981

[Pustulinae WATERHOUSE, 1981, p. 71]

Medium to large size; low rugae; spine base pustules may not be arranged in bands; buttress plates, cardinal process pit absent. *Lower Carboniferous (upper Tournaisian–Viséan).*

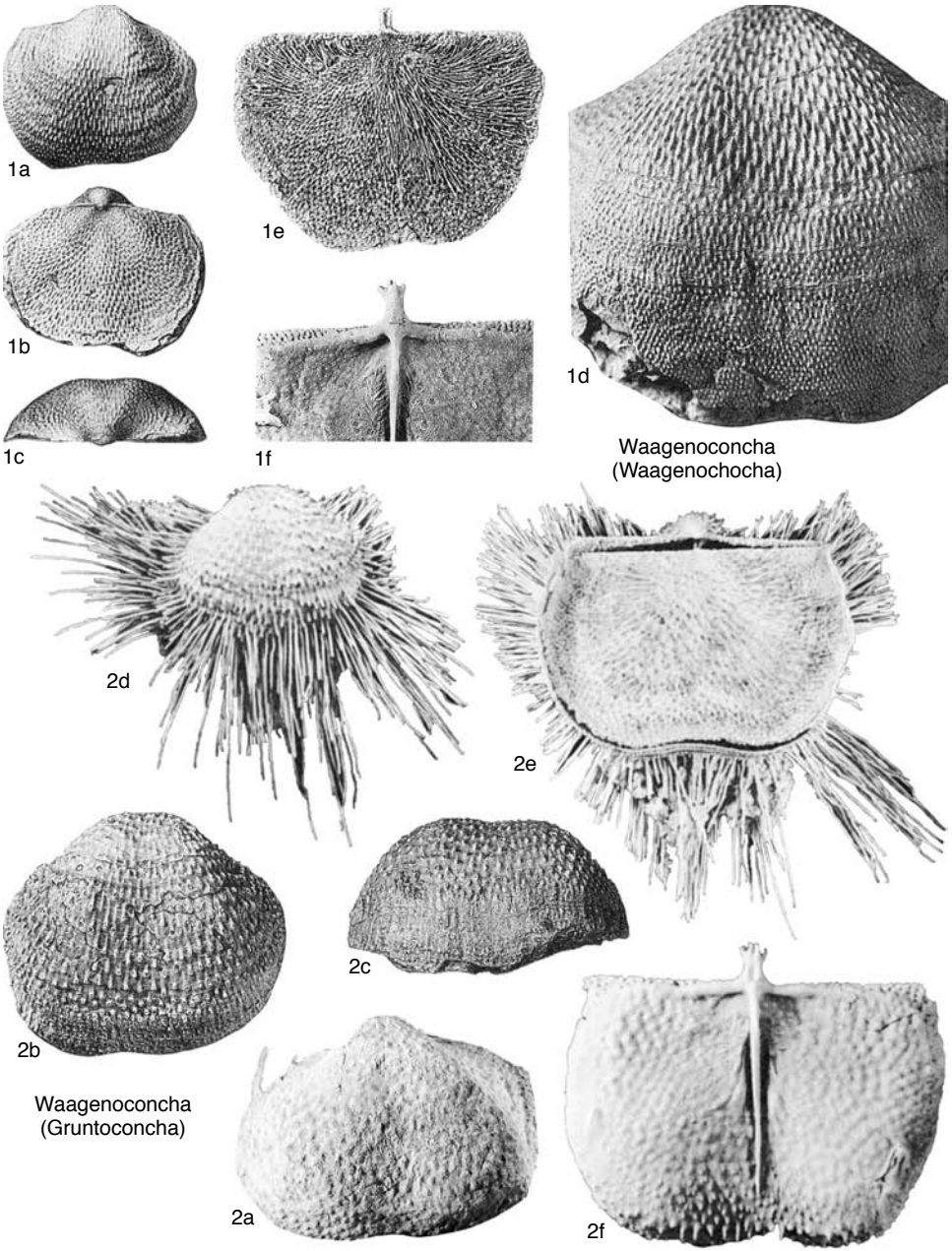

FIG. 357. Echinoconchidae (p. 517–518).

Pustula THOMAS, 1914, p. 259 [**Producta pustulosa* PHILLIPS, 1836, p. 216; OD]. Outline subrectangular with weak ventral sulcus, dorsal median fold, almost planoconvex, trails minimal; spine bases elongate, in irregular concentric bands with weak spine differentiation; cardinal process narrow, dorsal face trifid; cardinal ridges diminish toward ears, no marginal ridges. *Lower Carboniferous (Viséan):* Eurasia, northern Africa, ?North America.——FIG. 359,*1a–f.* **P. pustulosa* (PHILLIPS), Asbian–Brigantian; *a,* holotype, viewed anterolaterally, Lancashire, British Isles, BMNH B419, ×1; *b–e,* specimen viewed ventrally, posteriorly, laterally, dorsally, Staffordshire, ×1 (new); *f,*

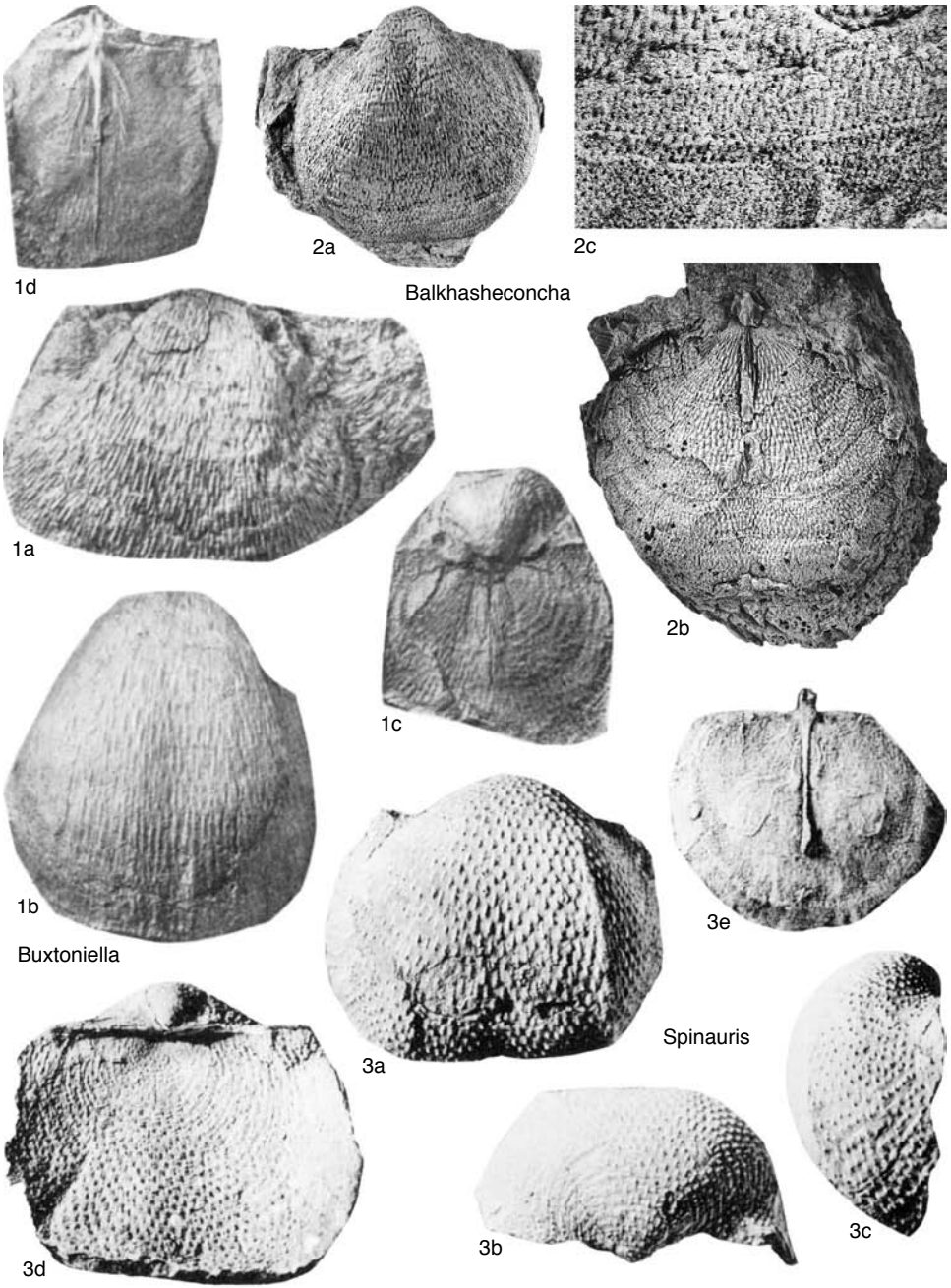

FIG. 358. Echinoconchidae (p. 518).

incomplete dorsal valve interior, Scotland, ×1 (Muir-Wood & Cooper, 1960).

?Etheridgina OEHLERT, 1887b, p. 1278 [**Productus complectens* ETHERIDGE, 1876, p. 462; OD]. Poorly known, possibly representing the young of more than one taxon; ventral valves around 3 mm wide, attached by clasping spines, rugae bearing scattered spines; associated dorsal valves, similarly rugose, spinose; quadrifid cardinal process supported by cardinal ridges, may also be buttress plates. *Lower*

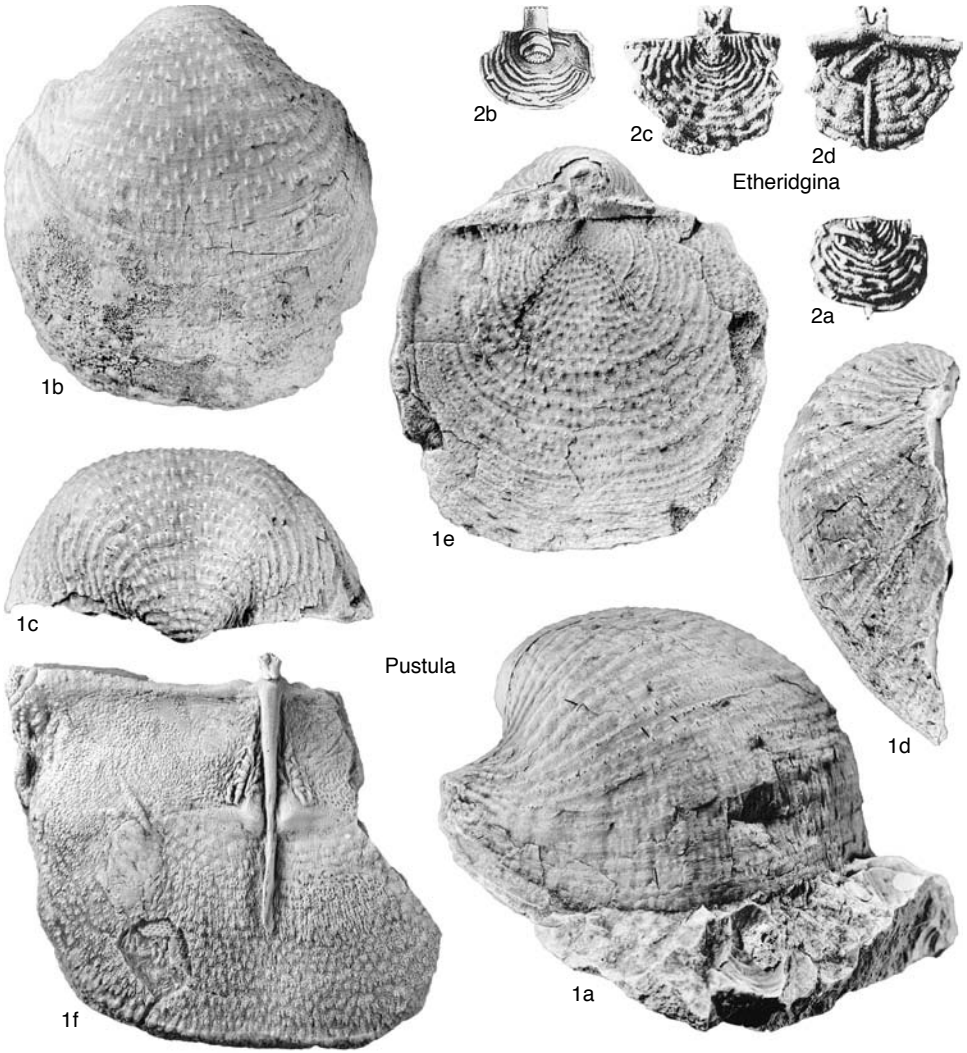

FIG. 359. Echinoconchidae (p. 519–521).

Carboniferous (Viséan): British Isles.——FIG. 359,*2a–d. *E. complectens* (ETHERIDGE), Brigantian, East Lothian; *a,* ventral valve exterior, ×5; *b,* ventral valve clasping crinoid stem, ×7; *c,d,* incomplete dorsal valve exterior, interior, ×5 (Muir-Wood & Cooper, 1960).

Scutepustula SARYTCHEVA in SARYTCHEVA & others, 1963, p. 165 [**Productus (Waagenoconcha) scutelatus* BALASHOVA, 1955, p. 146; OD]. Size medium; outline subcircular, closely spaced rugae bearing well-differentiated bands of elongate spine bases; otherwise resembles *Pustula. Lower Carboniferous (upper Tournaisian):* Eurasia, North America.——FIG. 360,*1a–e. *S. scutelata* (BALASHOVA), upper Tournaisian, southeastern Ural Mountains; *a,b,* shell viewed ventrally and with corpus removed, exposing part of dorsal valve external mold, ×1; *c,* ventral ornament viewed posterolaterally, ×3; *d,* ventral ornament viewed anteromedianly showing spine bases, ×5; *e,* ventral valve in lateral profile, ×1 (Sarytcheva & others, 1963).

?Septarinia MUIR-WOOD & COOPER, 1960, p. 251 [**Productus leuchtenbergensis* DE KONINCK, 1847a, p. 226; OD]. Ornamentation resembles *Pustula* on disks, but spines in concentric bands anteriorly, with more prominent dorsal median fold; ventral umbo interior with low median septum. *Lower Carboniferous (Asbian):* western Europe.——FIG. 360,*2a–f. *S. leuchtenbergensis* (DE KONINCK), Asbian; *a,b,* lectotype, internal mold, viewed

posteriorly, dorsally, Visé, Belgium, BMNH BD 193, ×1.5 (Mundy & Brunton, 1983); *c,* latex replica of posterior corpus cavity showing median septa, Visé, Belgium, ×1.5 (Muir-Wood & Cooper, 1960); *d–f,* shell viewed ventrally, laterally, anteriorly, Cork, Ireland, ×1 (Mundy & Brunton, 1983).

Family SENTOSIIDAE McKellar, 1970

[Sentosiidae McKellar, 1970, p. 27]

Echinoconchoids having shallow corpus cavity; concentric bands, spine differentiation commonly absent. *Middle Devonian (Givetian)–Upper Permian (Changhsingian).*

Subfamily SENTOSIINAE McKellar, 1970

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 928, *ex* Sentosiidae McKellar, 1970, p. 27]

Sentosiids without teeth; spines thin, may have elongate bases. *Upper Devonian (Famennian)–Upper Permian (Changhsingian).*

Tribe SENTOSIINI McKellar, 1970

[*nom. transl.* Brunton, Lazarev, & Grant, 1995, p. 929, *ex* Sentosiidae McKellar, 1970, p. 27]

Concentric rugae or lamellae may be as bands anteriorly. *Upper Devonian (Famennian)–Upper Permian (Changhsingian).*

Sentosia Muir-Wood & Cooper, 1960, p. 196 [**Krotovia praecursor* Stainbrook, 1947, p. 313; OD]. Size small to medium; outline transversely elliptical, ventral umbo small; rugae delicate, irregular, associated with fine prostrate spines from small rounded bases; cardinal process bilobed, quadrifid, lateral ridges short, only slightly divergent from hinge. *Upper Devonian (Famennian):* North America, ?northern Africa, Europe.——Fig. 361,*1a–e. *S. praecursor* (Stainbrook), Famennian, New Mexico; *a–c,* shell viewed ventrally, posteriorly, laterally, ×1; *d,* shell viewed dorsally, ×2; *e,* part of dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Alatoproductus Jing & Zhu in Jing & Hu, 1978, p. 120 [**A. truncatus;* OD] [=*Chenxianoproductus* Liao & Meng, 1986, p. 79 (type, *C. nitens;* OD); ?=*Chonostegoidella* Li & Yang in Li, Yang, & Feng, 1986, p. 219 (type, *C. longlinensis;* OD)]. Small to medium size, subtrigonal in outline with hinge less than maximum width; small cicatrix present in some; ventral median sulcus shallow; dorsal disk gently concave, trail short; short elongate spine bases with suberect fine spines becoming weakly arranged concentrically anteriorly; interiors poorly known, but with lateral ridges curving to lateral margins. *?Lower Permian, Upper Permian (Kazanian–Changhsingian):* China.——Fig. 361, *2a,b. *A. truncatus,* Kunfeng Formation, Anhui; dorsal valve external mold, interior, ×1.5 (Jin & Hu, 1978).——Fig. 361,*2c,d. A. nitens* Liao & Meng, Upper Permian, Hunan; *c,* holotype, ventral valve exterior, NIGP 74181, ×1.5; *d,* external mold of dorsal valve, ×2 (new).

Jakutella Abramov, 1970, p. 119 [**J. sarytchevae;* OD]. Medium; ventral profile strongly convex; concentric ornament anteriorly lamellose, somewhat resembling *Stegacanthia;* no differentiation of spines, arranged quincuncially posteriorly; interiors unknown. *Upper Carboniferous (Moscovian–Kasimovian):* northern Asia.——Fig. 361,*4a–d. *J. sarytchevae,* Moscovian, Yakutsk; *a,* anterior view of ventral valve exterior, ×1 (Abramov, 1970); *b,c,* posteroventral, lateral views of ventral valve, ×1; *d,* external mold of dorsal valve, ×1 (new).

Laminatia Muir-Wood & Cooper, 1960, p. 189 [**Productella laminata* Kindle, 1909, p. 18; OD]. Small; gently concavoconvex; concentric ornament strong, lamellose; spines differentiated into bands and by size; lateral ridges short, divergent. *Upper Devonian (Famennian):* southern North America, Australia, ?Kazakhstan.——Fig. 362,*1a–f. *L. laminata* (Kindle), uppermost Famennian, New Mexico; *a,* ventral valve exterior, ×2; *b–e,* shell viewed anteriorly, laterally, posteriorly, dorsally, ×2; *f,* dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Malloproductus Tachibana, 1981, p. 62, *nom. nov. pro Nodella* Tachibana, 1964, p. 38 [**M. pexus;* OD]. Size medium; similar to *Sentosia,* but possibly with longer fine spines, extending almost radially; cardinal process elongate, median septum long, narrow. *Upper Devonian (Famennian):* Japan.——Fig. 362,*3a–c. *M. pexus,* Famennian, northeastern Japan; *a,* ventral valve exterior with corona of spines, squashed, ×1; *b,* replica of dorsal valve exterior, including cardinal process, ×1.5; *c,* replica of dorsal valve interior, ×1 (new).

Markamia Jin Yu-gan & Shi Quan in Jin & others, 1985, p. 192 [**M. transversa;* OD] [=*Tuberella* Li in Li, Yang, & Feng, 1986, p. 222 (type, *T. typica;* OD); *Uraloconchus* Lazarev, 1990, p. 112 (type, *Productus jakovlevi* Chernyschev, 1902, p. 300; OD)]. Size small to medium; outline transverse, weakly concavoconvex; spines prostrate, coarse posteriorly on narrow lamellose bands separated by narrower bands of smooth shell; dorsal spines fine; interiors unknown. *Upper Carboniferous (Gzhelian)–Lower Permian (Artinskian):* China, Tibet, western Ural Mountains.——Fig. 362,*4a,b. *M. transversa,* Gzhelian–Asselian, Xizang; *a,* ventral valve exterior, NIGP 60757, ×1; *b,* dorsal valve exterior, ×1 (Jin & others, 1985).

Productellana Stainbrook, 1950, p. 373 [**P. bifaria;* OD]. Small; outline subcircular, reportedly with short interarea, open delthyrium; rugae weak, irregular, slightly lamellose; spines widely spaced, weakly concentric. *Upper Devonian (Famennian):* North America, ?China.——Fig. 362,*2a–e. *P. bifaria,* Famennian, Aplington, Iowa; *a–c,* holotype,

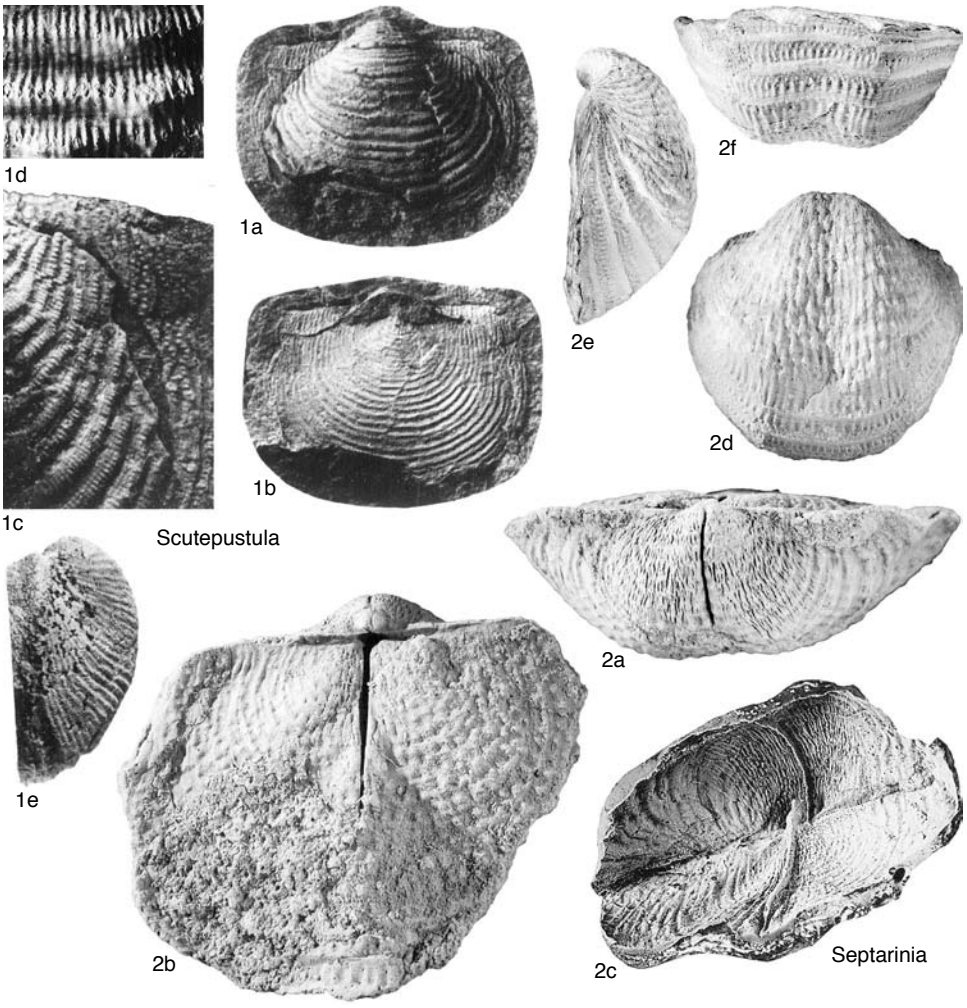

FIG. 360. Echinoconchidae (p. 521–522).

viewed ventrally, laterally, anteriorly, SUI 21656A, ×1; *d,* shell viewed dorsally, ×1.5; *e,* shell viewed dorsally, ×3 (new).

Sentosioides LAZAREV in LAZAREV & SUUR'SUREN, 1992, p. 69 [**S. tsagankhalginensis;* OD]. Ventral umbo moderately inflated; elongate spine-base pustules on both valves, ventral spines thicker than *Sentosia;* weak concentric ornament. *Upper Devonian (upper Famennian):* Russia, Asia.——FIG. 362,*5a–d.* **S. tsagankhalginensis,* uppermost Famennian, Gobi Altai, Mongolia; *a,* incomplete ventral valve exterior, ×2 (new); *b,* replica of incomplete dorsal valve exterior, ×1.5; *c,* part of dorsal valve interior plus external mold, ×1.6 (new); *d,* holotype, incomplete dorsal valve interior, PIN 3385/1050, ×1 (Lazarev & Suur'suren, 1992).

Stegacanthia MUIR-WOOD & COOPER, 1960, p. 198 [**S. bowsheri;* OD]. Size medium; concavoconvex with short trails, ornament lamellose, each band with elongate spine bases, spines prostrate; lateral ridges diverge toward ears. *Lower Carboniferous (upper Tournaisian–lower Viséan):* southern North America, ?northern Africa, Europe.——FIG. 361,*3a–e.* **S. bowsheri,* Ivorian, New Mexico; *a–d,* holotype, viewed ventrally, anteriorly, laterally, dorsally, USNM 123963, ×1; *e,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Tribe BAGRASIINI Nalivkin, 1979

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 929, *ex* Bagrasiinae NALIVKIN, 1979, p. 109]

Elongate spine bases simulate ribs on both valves. *Lower Carboniferous (upper Tournaisian–lower Viséan).*

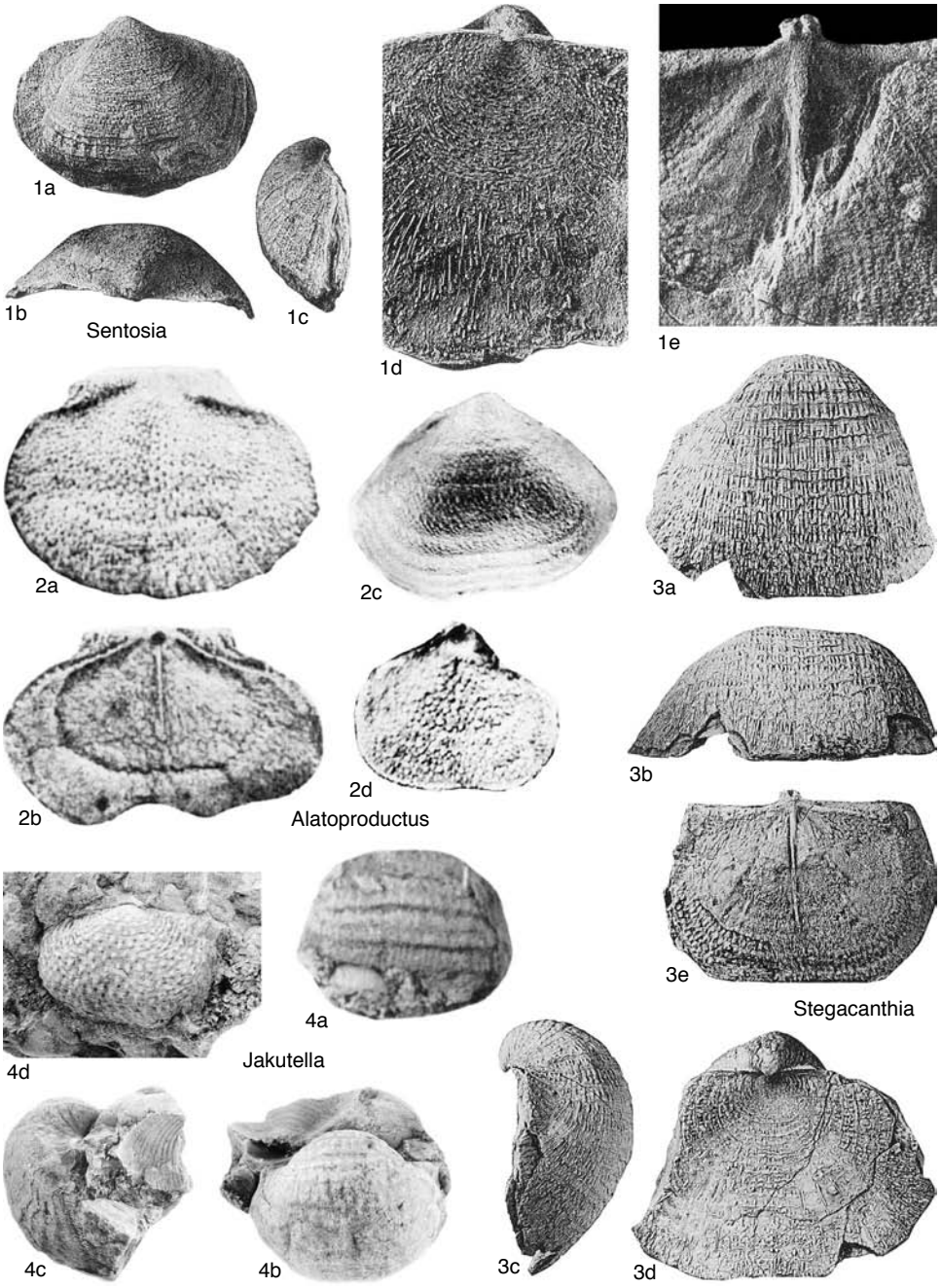

FIG. 361. Sentosiidae (p. 522–523).

Ericiatia MUIR-WOOD & COOPER, 1960, p. 172 [**Productus newberryi* HALL, 1857, p. 180; OD; =*Productella newberryi* HALL, 1883, pl. 49, fig. 1–3] [=*Bagrasia* NALIVKIN in SARYTCHEVA, LICHAREW, & SOKOLSKAJA, 1960, p. 231 (type, *Productus choneti-formis* KRESTOVNIKOV & KARPYSHEV, 1948, p. 48)]. Size small to medium; outline subcircular to transverse, elongate spine bases simulate ribbing over

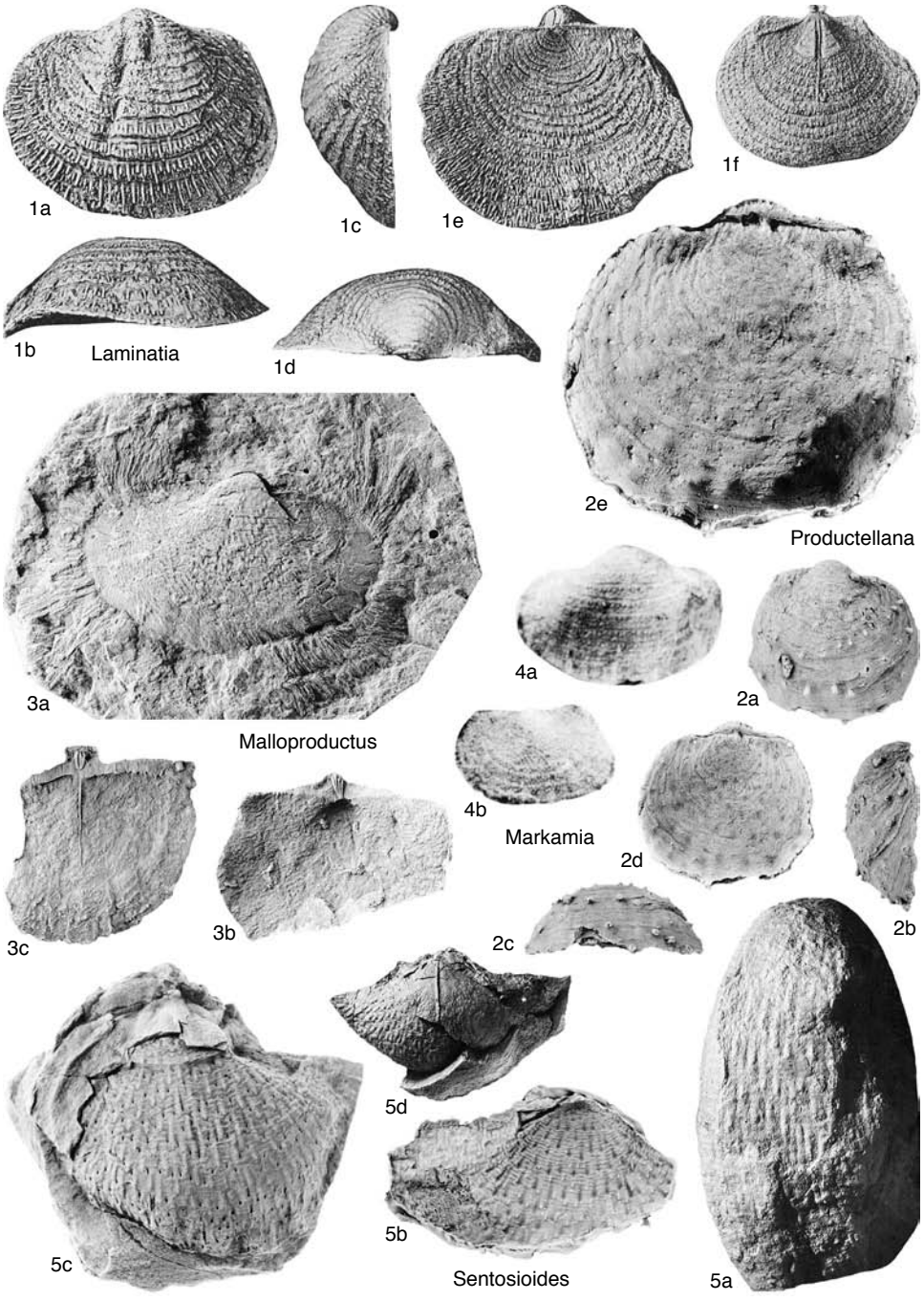

FIG. 362. Sentosiidae (p. 522–523).

complete shell; cardinal process weakly supported by short lateral ridges. *Lower Carboniferous (upper Tournaisian–lower Viséan):* western Ural Mountains, North America.——FIG. 363*a–d.* **E. newberryi* (HALL), upper Kinderhookian–lower Osagean, Ohio; *a,* ventral valve exterior, ×1; *b,* lateral profile

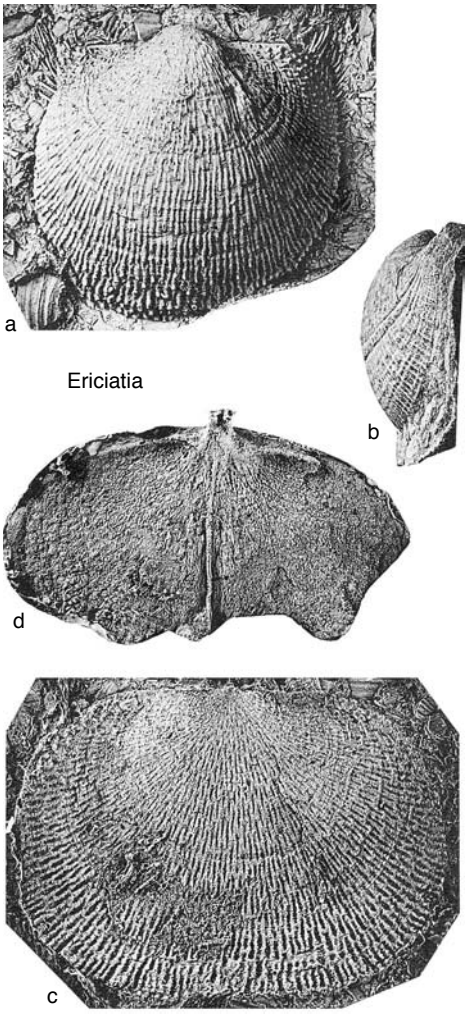

FIG. 363. Sentosiidae (p. 524–526).

of ventral valve, ×1; *c,* replica of dorsal valve exterior, ×1; *d,* replica of incomplete dorsal valve interior, ×1.5 (Muir-Wood & Cooper, 1960).

Subfamily CAUCASIPRODUCTINAE Lazarev, 1987

[Caucasiproductinae LAZAREV, 1987, p. 49]

Sentosiids with teeth, sockets; ventral spines relatively thick, suberect; lateral ridges short, divergent anteriorly. *Middle Devonian (Givetian)–Upper Devonian (Famennian).*

Caucasiproductus LAZAREV, 1987, p. 50[47] [**C. gretchishnikovae;* OD]. Size small; narrow ginglymus; thick-walled with up to 0.5 mm thick ventral spines; short ventral median septum; cardinal process strongly V-shaped. *Middle Devonian (Givetian):* Transcaucasia.——FIG. 364,*2a. *C. gretchishnikovae,* Givetian, Transcaucasia; holotype, ventral valve exterior, PIN 4127/103, ×3 (Lazarev, 1987).——FIG. 364,*2b–e. Caucasiproductus* sp.; *b,c,* dorsal, posterior views of shell, ×3 (Lazarev, 1987); *d,* ventral valve internal mold plus shell anterolaterally, ×3; *e,* dorsal valve interior, ×3 (Lazarev, 1990).

Praewaagenoconcha SOKOLSKAYA, 1948, p. 132 [**Productus orelianus* VON MÖLLER, 1871, p. 389; OD]. Small; thinner shelled than *Caucasiproductus,* spines relatively fine in roughly concentric arrangement, commonly with spine bearing median ridge; no ventral median septum. *Upper Devonian (Famennian):* eastern Europe.——FIG. 364,*3a–d. *P. oreliana* (VON MÖLLER), Famennian, Moscow basin; *a,b,* ventral valve exterior viewed ventrally, laterally, ×2; *c,* shell viewed posteriorly, ×2; *d,* shell viewed dorsally showing spines, ×2 (new).

Strophoproductus NALIVKIN, 1937, p. 46 [**Productella hystricula* HALL, 1867c, p. 178; OD]. Small; undulose concentric ornament; weak elongate spine bases, spines probably recumbent; cardinal process strongly bilobed internally, with pit and short socket ridges. *Upper Devonian (Frasnian):* North America, Eurasia.——FIG. 364,*1a–c. *S. hystriculus* (HALL), Frasnian, New York; *a,* ventral valve exterior, ×2; *b,* dorsal valve exterior, ×2; *c,* dorsal valve interior on left, ×2 (Muir-Wood & Cooper, 1960).

Family UNCERTAIN

Septiconcha TERMIER & others, 1974, p. 125 [**S. taeniosa;* OD]. Insufficient morphology to assign, but if deep corpus cavity, then assigned to Juresaninae. *Upper Permian (Kazanian):* Afghanistan.

Superfamily LINOPRODUCTOIDEA Stehli, 1954

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 929, *ex* Linoproductinae STEHLI, 1954, p. 319] [=Striatoidea NALIVKIN, 1979, p. 105]

Trail commonly long but simple; ribbing regular, entire, relatively fine, commonly delicately sinuose; ventral spines at hinge, diverse on rest of valve, never few, thick and symmetrical; dorsal valve without spines except grandaurispinins and some gigantoproductins. *Lower Devonian (Pragian)–Upper Permian (upper Tatarian).*

Family LINOPRODUCTIDAE Stehli, 1954

[*nom. transl.* MUIR-WOOD & COOPER, 1960, p. 296, *ex* Linoproductinae STEHLI, 1954, p. 319]

Linoproductoids with deep corpus cavity, distinct trails; commonly no dorsal spines.

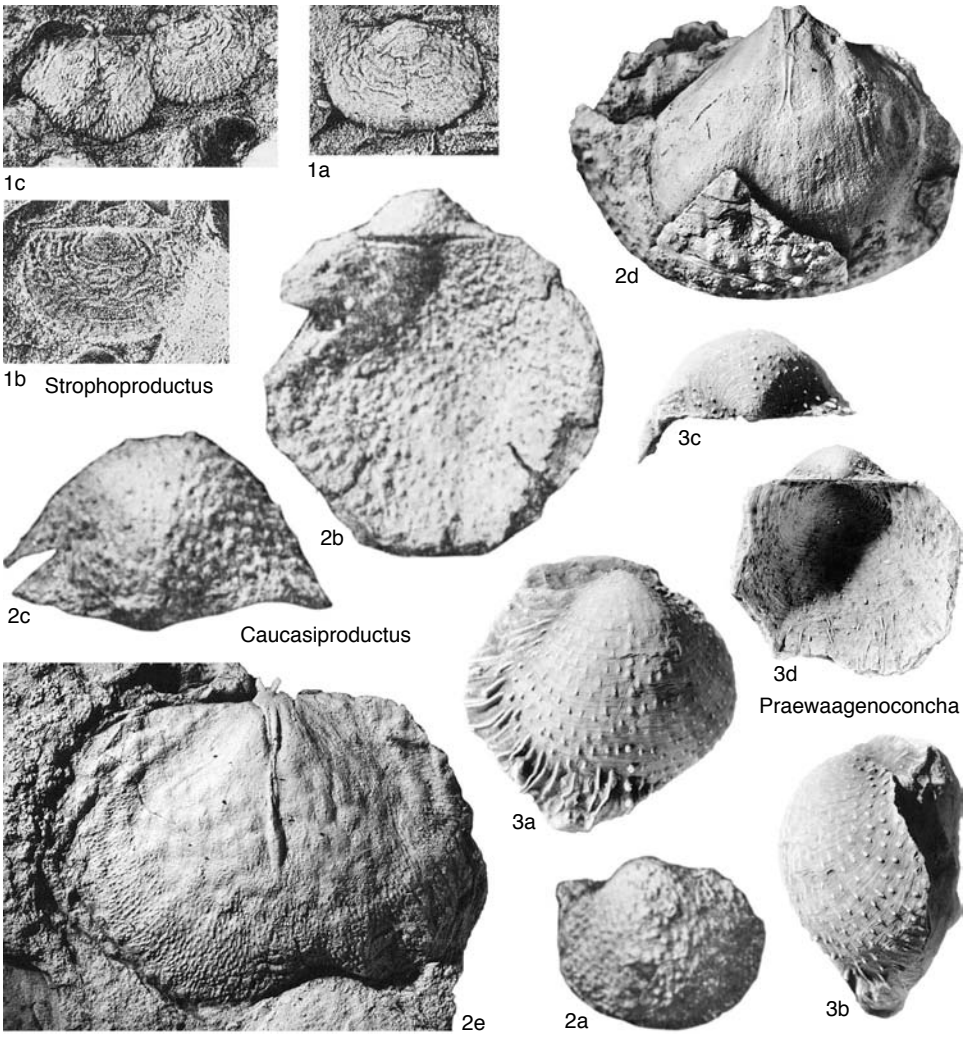

FIG. 364. Sentosiidae (p. 526).

Lower Carboniferous (middle Viséan)–Upper Permian (Tatarian).

Subfamily LINOPRODUCTINAE Stehli, 1954

[Linoproductinae STEHLI, 1954, p. 319] [=Fluctuariinae NALIVKIN, 1979, p. 107; Stepanoviellinae WATERHOUSE, 1975, p. 12]

Linoproductids without marginal structures or dorsal spines. *Lower Carboniferous (middle Viséan)–Upper Permian (Kazanian).*

Linoproductus CHAO, 1927b, p. 128 [**Productus cora* D'ORBIGNY, 1842, p. 55; OD] [=*Euproductus* WHITEHOUSE, 1928, p. 281, obj.; *Cora* FREDERICKS, 1928, p. 781, 790, obj; *Levisapicus* TONG in TONG & others, 1990, p. 66[100] (type, *L. giganteus*)]. Medium to large, outline elongate subcircular; ventral profile inflated posteriorly, dorsal corpus gently concave; hinge commonly widest part of shell; ribbing complete, tends to be distorted at spine bases, which are widely scattered ventrally; spines also closely set in one or two rows along hinge; rugae on ventral ears, flanks, dorsal corpus; cardinal process sessile, trifid, supported by lateral ridges; adductor scars, brachial ridges weakly marked. [*Levisapicus,* Zhigou Formation (Sakmarian) of Sichuan, is reported as having a group of spines on ears.] *upper Upper Carboniferous–Upper Permian (Kazanian):* cosmopolitan.——FIG. 365,*1a–f.* **L. cora* (D'ORBIGNY), Lower Permian, Bolivia (Cochabamba); *a–d,* shell viewed ventrally, posteriorly, dorsally, laterally, ×1; *e,* large example viewed

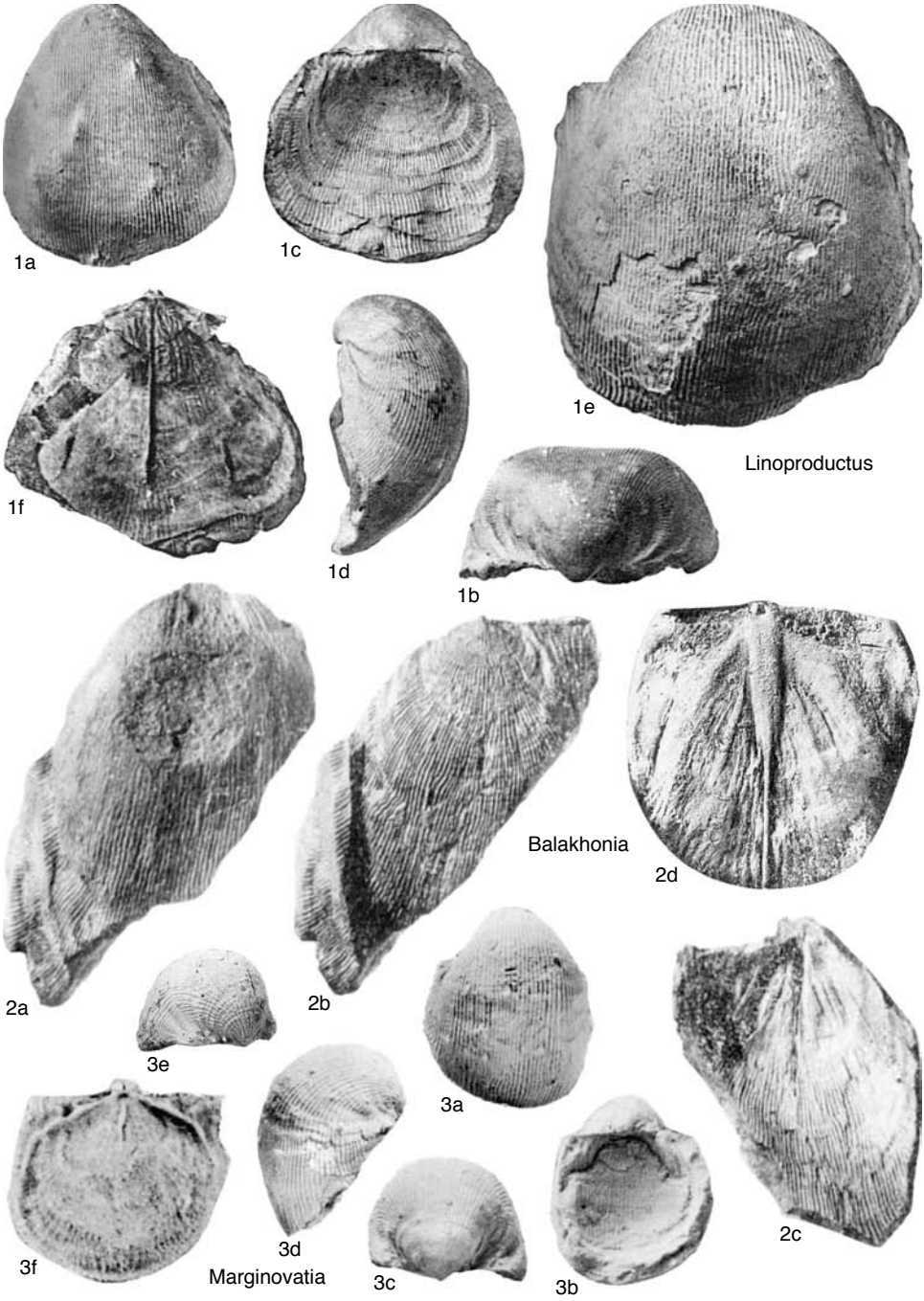

FIG. 365. Linoproductidae (p. 527–530).

ventrally, ×1; *f,* incomplete dorsal valve interior, ×1 (Kozłowski, 1914).

Balakhonia SARYTCHEVA in SARYTCHEVA & others, 1963, p. 231 [**B. ostrogensis;* OD]. Medium size; ventral profile convex with long trail, ears prominent, flanks gently sloping; spines at hinge, rarely on ventral corpus where finer than ribs; cardinal process sessile with well-separated lobes; dorsal adductor scars di-

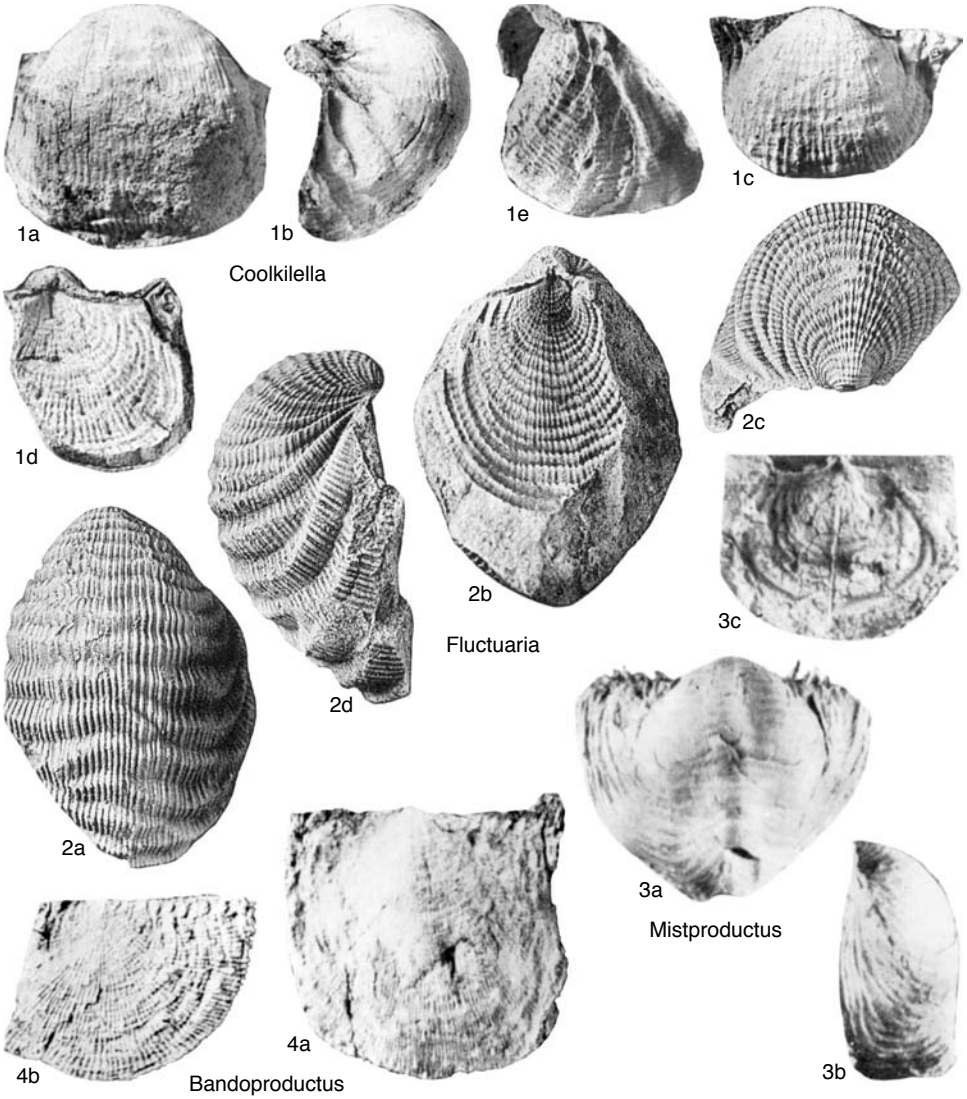

FIG. 366. Linoproductidae (p. 529–530).

vided, bordered posterolaterally by ridges. *upper Lower Carboniferous (upper Viséan–lower Serpukhovian), ?Upper Carboniferous (Bashkirian):* Eurasia, ?northern Africa.——FIG. 365,*2a–d. *B. ostrogensis,* upper Viséan–Serpukhovian, Ostrog Formation, Kuzbass; *a–c,* holotype, internal mold of ventral valve, dorsal valve external, internal molds, PIN 1493/278, ×1; *d,* incomplete dorsal valve interior, ×2 (Sarytcheva & others, 1963).

Bandoproductus JING & SUN, 1981, p. 138 [**B. hemiglobica;* OD]. Medium size, resembling *Linoproductus,* but with fine ventral spines no wider than ribs on corpus, single row of hinge spines; trails short; thin shelled. *Upper Carboniferous (Gzhelian)–Lower Permian (Sakmarian):* Tibet (Xizang).——FIG. 366,*4a,b. *B. hemiglobica,* Lower Permian, Bando Group, Tibet; *a,* ventral valve exterior, ×1; *b,* external mold of incomplete dorsal valve, ×1 (Jin & Sun, 1981).

Coolkilella ARCHBOLD, 1993, p. 14 [**Cancrinella coolkilyaensis* ARCHBOLD, 1983b, p. 241; OD]. Resembles *Cancrinella,* but with planoconvex corpus, strongly geniculate dorsal valve, long trails; rugae at ears, weak on disks; spines in two rows on ears, sparse on venter from weakly developed, elongate bases. *upper Lower Permian (upper Artinskian–lower Kungurian):* Western Australia.——FIG. 366,*1a–e.* *C. coolkilyaensis* (ARCHBOLD), upper Lower

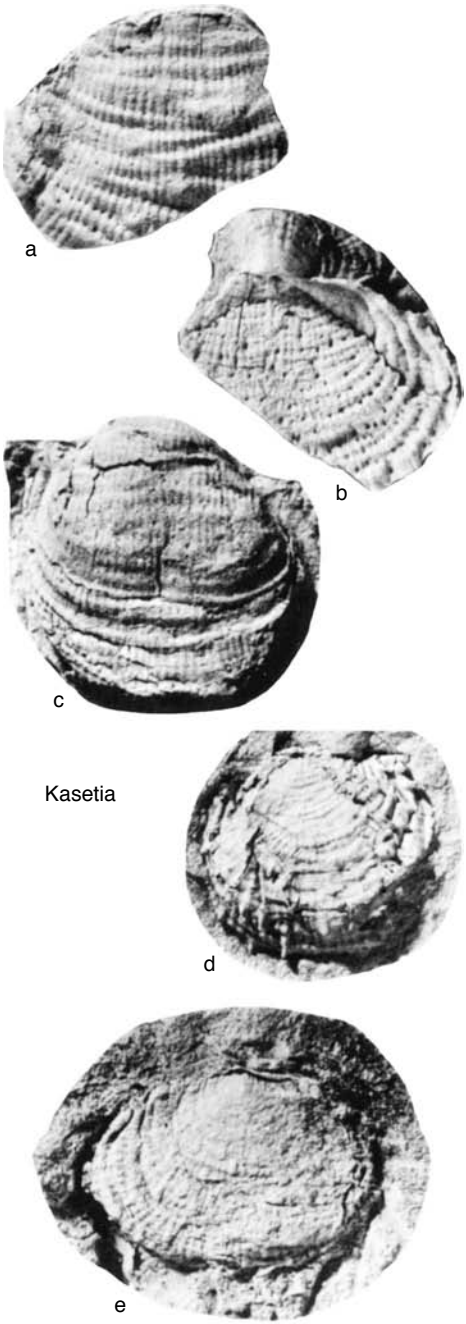

FIG. 367. Linoproductidae (p. 530).

Permian, Coolkilya Greywacke, Carnarvon basin; *a,b,* holotype, internal mold viewed anteroventrally, laterally, CPC 19920A, ×1.4; *c,* internal mold viewed posteroventrally, ×1.5; *d,* incomplete internal mold viewed dorsally, ×1.5; *e,* external mold of dorsal valve viewed laterally showing strong geniculation, ×1.4 (Archbold, 1983b).

Fluctuaria MUIR-WOOD & COOPER, 1960, p. 303 [**Productus undatus* DEFRANCE, 1826, p. 354; OD]. Small; elongate, nongeniculate profile; rugae prominent, entire, increasing in size anteriorly; spines at hinge, ears, otherwise rare; cardinal process small, sessile; cardinal ridges weak. *Lower Carboniferous (upper Viséan), ?Upper Carboniferous (?lower Moscovian):* Eurasia, ?North America.——FIG. 366,*2a–d.* **F. undata* (DEFRANCE), Asbian, Visé, Belgium; ventral, dorsal, posterior, lateral views of specimen, ×2 (Muir-Wood & Cooper, 1960).

Kasetia WATERHOUSE, 1981, p. 89 [**K. kaseti;* OD]. Resembles *Coolkilella,* but small with irregular discontinuous rugae; spines in clusters on ears, weakly developed spine bases. *Lower Permian (Artinskian):* southern Thailand.——FIG. 367*a–e.* **K. kaseti,* Lower Permian, Ko Yao Noi Formation, Thailand; *a,b,* holotype, incomplete internal mold of ventral, dorsal valves, TBR 287, ×3; *c,* ventral valve internal mold, ×3; *d,* replica of ventral valve exterior, ×3; *e,* exfoliated dorsal valve interior, ×3 (Waterhouse, 1981).

Marginovatia GORDON & HENRY, 1990, p. 533 [**Productus ovatus* var. *minor* SNIDER, 1915, p. 79; OD]. Small, less than 20 mm wide; spines in one or two rows near ventral hinge, others sparsely scattered; rugae at ears, less commonly complete on ventral disk; marginal ridges in both valves at start of trails. *Lower Carboniferous (middle Viséan)–Upper Carboniferous (Bashkirian):* USA, Arctic Canada. ——FIG. 365,*3a–f.* **M. minor* (SNIDER), Chesterian, Oklahoma; *a–d,* ventral, dorsal, posterior, lateral views of shell, ×2; *e,* posterolateral view of shell, ×2; *f,* dorsal valve interior, ×3 (Gordon & Henry, 1990).

?Mistproductus YANG DE-LI, 1991, p. 81[90] [**M. eucallusus;* OD]. Poorly known, similar to *Linoproductus,* but may be folded anteriorly, possibly resulting from shell damage, and reportedly with cicatrix surrounded by rhizoid spines on ears, flanks; corpus cavity deep. *Lower Permian (Artinskian–Kungurian):* southern China.——FIG. 366,*3a–c.* **M. eucallusus,* Lower Permian, Guangxi; *a,b,* ventral valve exterior, lateral view, ×1; *c,* dorsal valve interior, ×1.5 (Yang De-li, 1991).

Subfamily ANIDANTHINAE Waterhouse, 1968

[Anidanthinae WATERHOUSE, 1968a, p. 1172]

Linoproductids with well-developed ears, marginal structures; concentric lamellae (series of trails) commonly on dorsal valve; corpus cavity commonly deep. *Upper Carboniferous (Bashkirian)–Upper Permian (Capitanian).*

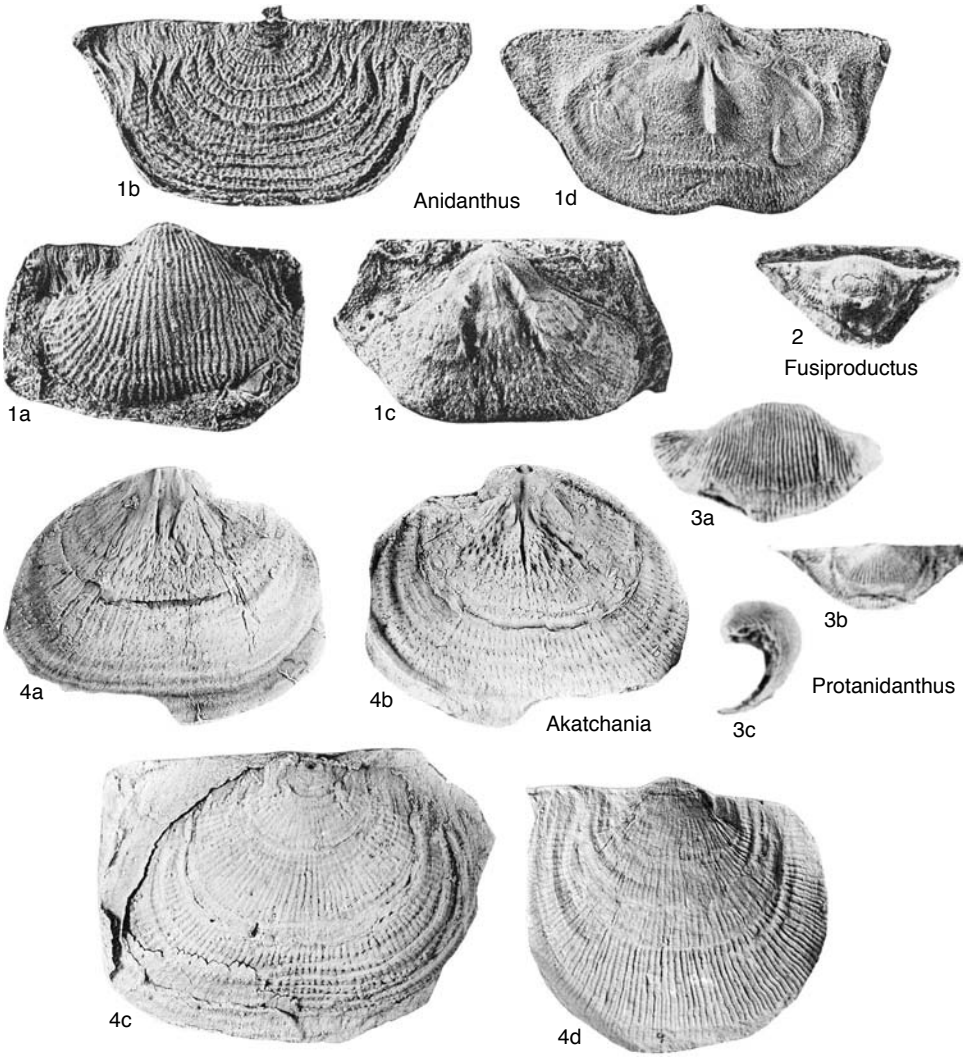

FIG. 368. Linoproductidae (p. 531–533).

Anidanthus HILL, 1950, p. 9 [**Linoproductus springsurensis* BOOKER, 1932, p. 67; OD] [=*Anidanthus* WHITEHOUSE, 1928, p. 282, *nom. nud.; ?Pseudomarginifera* STEPANOV, 1934, p. 56 (type, *Productus ussuricus* FREDERICKS, 1924, p. 8)]. Medium size, transverse shells with large, well-differentiated ears forming maximum width; ribbing on both valves, except ears; rugae lamellose dorsally; spines in row near hinge, widely scattered on corpus, trail; dorsal interior with thickened shell posteromedianly, median septum about half disk length. *upper Lower Permian–lower Upper Permian:* Australia, northern and central Asia, central America.——FIG. 368,*1a–d.* **A. springsurensis* (BOOKER), New South Wales; *a,* ventral valve exterior, ×2; *b,* dorsal valve exterior, ×2; *c,* ventral valve interior, ×2; *d,* replica of dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Akatchania KLETS in ABRAMOV & GRIGORJEVA, 1988, p. 135 [**A. plana;* OD]. Medium size, hinge width approximately equal to corpus width; cavity shallow; rugae on ventral flanks and ears, dorsal valve with widely separated lamellae; spines near hinge only, extending posterolaterally; median septum short; lateral, marginal ridges complete in both valves. *Lower Permian (Asselian):* central Siberia. ——FIG. 368,*4a–d.* **A. plana,* Lower Permian, Katchan Formation, southern Verkhoyan; *a,b,* holotype, internal mold viewed ventrally, dorsally,

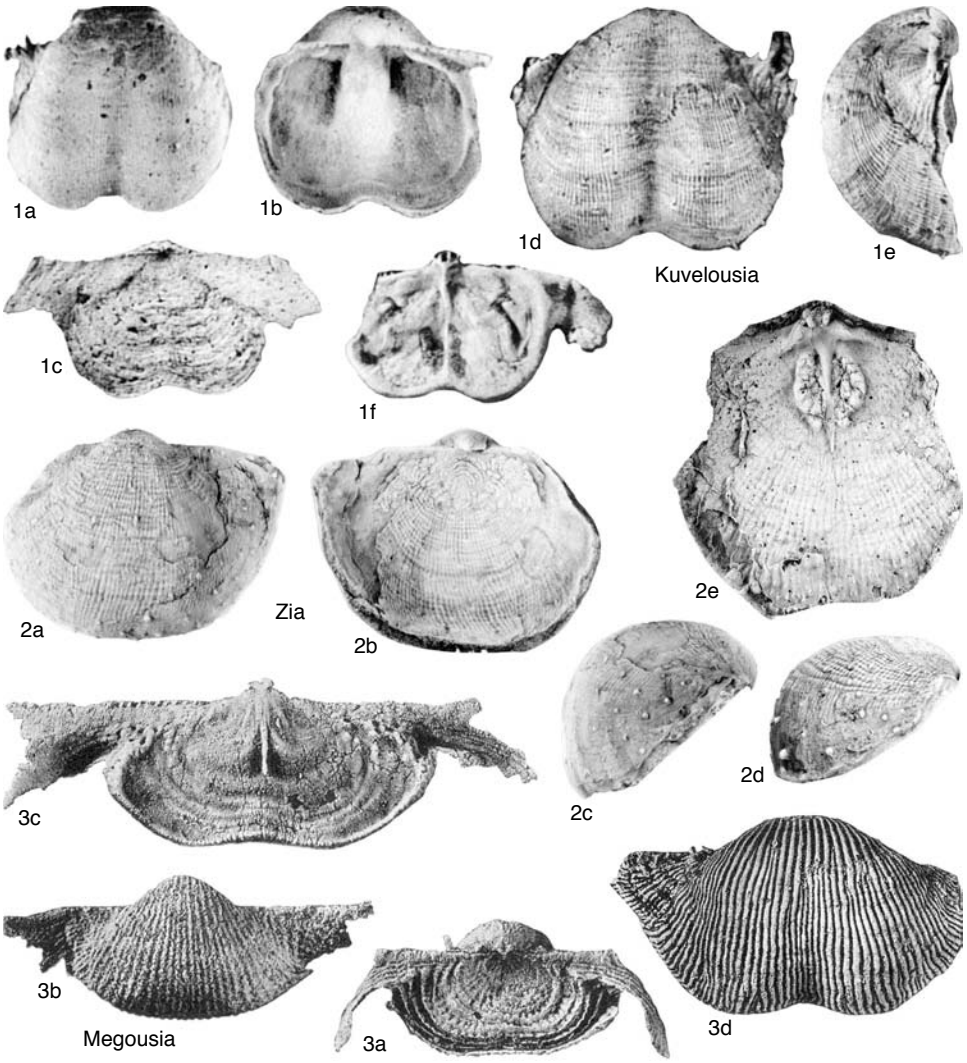

FIG. 369. Linoproductidae (p. 532–533).

M.Ch. 14019-1/50, ×2; *c,* dorsal valve external mold, ×2 (Abramov & Grigorjeva, 1988); *d,* ventral valve exterior, ×2 (new).

Fusiproductus WATERHOUSE, 1975, p. 12 [**Linoproductus fusiformis* HUANG, 1932, p. 45; OD]. Poorly known small shells with highly enrolled ventral valve; outline wide with subtubular ventral ears; ribbing fine; spines single on ears, lacking on venter. *Upper Permian (Capitanian):* China (Guizhou), ?Urals, ?Siberia.——FIG. 368,*2. *F. fusiformis* (HUANG), Capitanian, Guizhou; ventral valve exterior, ×1 (HUANG, 1932).

Kuvelousia WATERHOUSE, 1968a, p. 1175 [**K. sphiva;* OD] [=*Nothokuvelousia* WATERHOUSE in WATERHOUSE & BRIGGS, 1986, p. 62 (type, *N. aurifera*)]. Resembles *Megousia,* but larger with dorsal valve heavily thickened; median septum may reach marginal ridge. *Upper Permian (Kazanian):* Arctic Canada, USA, eastern Australia.——FIG. 369,*1a–f.* **K. sphiva,* Kazanian, Degerbols Formation, Arctic Canada; *a–c,* holotype, ventral valve exterior, interior, dorsal valve exterior, GSC 22910, ×1; *d,e,* ventral valve exterior, viewed laterally, ×1; *f,* dorsal valve interior, ×1 (Waterhouse, 1968a).

Megousia MUIR-WOOD & COOPER, 1960, p. 309 [**M. auriculata;* OD]. Resembles *Anidanthus,* but ribbing on extended ears curving anterodorsally. *lower Upper Permian:* North America, eastern Australia, Tasmania.——FIG. 369,*3a–c.* **M. auriculata,* Upper Permian, Word Limestone, Texas; *a,* holotype,

viewed dorsally, USNM 124108b, ×2; *b,* ventral valve exterior, ×2; *c,* dorsal valve interior, ×3 (Muir-Wood & Cooper, 1960).——Fig. 369,*3d. M. alata* (Cooper), Monos Formation, Sonora, Mexico; ventral valve exterior, ×2 (Muir-Wood & Cooper, 1960).

Protanidanthus Liao, 1979, p. 536[544] [**P. elegans;* OD]. Similar to *Anidanthus,* but lacks dorsal lamellae. *Lower Permian:* China.——Fig. 368,*3a–c. *P. elegans,* Asselian, Guizhou; *a,* ventral valve exterior, ×1; *b,* dorsal valve exterior, ×1; *c,* lateral view of shell, ×1 (Liao, 1979).

Zia Sutherland & Harlow, 1973, p. 59 [**Z. novamexicana;* OD] [=*Semilunataproductus* Han Tong-xiang in Han & others, 1987, p. 317 (type, *S. semilunatus;* OD)] Medium size, around 30 mm wide; outline subcircular, profile geniculate with flattened ventral disk; disks reticulate, trails ribbed; spines scattered on ventral valve, but larger on trail; cardinal process sessile, lateral ridges diverge into ear baffles. [*Semilunataproductus,* Gzhelian to Asselian of Shanxi, China, is minute, around 4 mm wide, with flattened (?cicatrix) ventral disk and somewhat rugose dorsal tail.] *Upper Carboniferous (Bashkirian)–Lower Permian (Asselian):* southern USA.——Fig. 369,*2a–e. *Z. novamexicana,* Morrowan, New Mexico; *a–c,* holotype, viewed ventrally, dorsally, laterally, OU 7790, ×1; *d,* lateral view of ventral valve exterior, ×1; *e,* incomplete replica of dorsal valve interior, ×1.5 (Sutherland & Harlow, 1973).

Subfamily GRANDAURISPININAE Lazarev, 1986

[Grandaurispininae Lazarev, 1986c, p. 32] [=Paucispinauriinae Waterhouse in Waterhouse & Briggs, 1986, p. 2]

Linoproductids with thin spines also on dorsal corpus; ribbing may be reduced; marginal structures, series of trails absent. *Upper Carboniferous (Gzhelian)–Upper Permian (Tatarian).*

Grandaurispina Muir-Wood & Cooper, 1960, p. 305 [**C. kingorum;* OD]. Medium size with hinge at maximum width; dorsal disk weakly concave with short trail; ribbing fine (capillae) commonly indistinct, rugae weak on dorsal disk; spines thick, in clusters on ears and flanks, thin with slightly elongate bases quincuncially arranged ventrally; dorsal valve with dimples, thin suberect spines; cardinal process sessile, trifid, lacking pit; lateral ridges short, medium septum long. *Upper Permian (Kazanian):* USA.——Fig. 370,*1a–d. *G. kingorum,* Upper Permian, Word Formation, Texas; *a,* holotype, viewed dorsally, USNM 123454, ×1.5; *b,* ventral valve exterior, ×1; *c,d,* dorsal valve viewed externally showing capillae, internally, ×2 (Muir-Wood & Cooper, 1960).

Cancrinella Fredericks, 1928, p. 784 [**Productus cancrini* de Verneuil, 1845, p. 245; OD] [=*Platycancrinella* Waterhouse, 1983b, p. 126 (type, *P. grandauris*)]. Small to medium size, corpus almost planoconvex, deep cavity; spines with elongate swollen bases on ribs, evenly distributed, clusters on ears, spines fine on dorsal valves; rugae weak on both valves; cardinal process sessile; lateral ridges close to hinge; median septum commonly divided posteriorly. [*Platycancrinella,* from Upper Permian of Nepal, said to differ by having less crowded spines on ears and flanks.] *Upper Carboniferous (Gzhelian)–Upper Permian (Wordian):* cosmopolitan.——Fig. 370,*2a–d. *C. cancrini* (de Verneuil), Lower Permian, Arctic Russia; *a–c,* shell viewed ventrally, dorsally, laterally, ×1; *d,* part of dorsal valve interior, ×4 (Sarytcheva, 1977).——Fig. 370,*2e,f. C. subquadrata* Cooper & Grant, Upper Permian, Word Formation, Texas; *e,* dorsal valve exterior, ×2; *f,* dorsal valve interior, ×1 (Cooper & Grant, 1975).——Fig. 370,*2g,h. C. altissima* (R. H. King), Gzhelian, Wayland Shale, Texas; shell viewed ventrally, dorsally, ×1 (Muir-Wood & Cooper, 1960).

Holotricharina Cooper & Grant, 1975, p. 1173 [**H. hirsuta;* OD]. Resembles *Grandaurispina* with ventral spines of two sizes, but lacks ventral ribbing. *Lower Permian–lower Upper Permian:* USA.——Fig. 371,*1a–e. *H. hirsuta,* Lower Permian, Road Canyon Formation, Texas; *a,* holotype, ventral valve exterior, USNM 149896a, ×1; *b,c,* ventral valve exterior viewed ventrally, laterally, ×1; *d,* shell viewed dorsally, ×2; *e,* dorsal valve interior, ×2 (Cooper & Grant, 1975).

Lyonia Archbold, 1983b, p. 244 [**Linoproductus cancriniformis* var. *lyoni* Prendergast, 1943, p. 24; OD]. Resembles *Cancrinella,* but with strong hinge spines, no ear clusters, dorsal spines developed anteriorly; cardinal process small, unusually sessile, unsupported by ridges, lacking clear lateral ridges. *Lower Permian (Sakmarian):* Western Australia, ?Himalayas.——Fig. 372,*1a–e. *L. lyoni* (Prendergast), Sakmarian, Lyons Group, Carnarvon basin; *a,* holotype, vental valve exterior, AMF 36530, ×1; *b,* ventral valve exterior, ×1; *c,* dorsal valve external mold, ×1; *d,* dorsal valve internal mold, ×1; *e,* replica of dorsal cardinalia, ×4.5 (Archbold, 1983b).

Paucispinauria Waterhouse, 1983b, p. 130 [**Terrakea concava* Waterhouse, 1964, p. 67; OD]. Similar to *Terrakea,* but possibly differing in its coarser ventral spines and band of coarse spines at base of dorsal trail. *upper Lower Permian–lower Upper Permian:* southern New Zealand, Australia.——Fig. 371,*2a–e. *P. concava* (Waterhouse), low Upper Permian, *Productus* Creek Limestone, Southland, New Zealand; *a,b,* holotype, ventral valve internal mold viewed posteriorly, replica of dorsal valve exterior, NZGS BR 200, ×2; *c,d,* ventral valve exterior viewed anteriorly, posteroventrally, ×2; *e,* replica of dorsal valve interior, ×2 (Waterhouse, 1964).

Stepanoviella Zavodowsky, 1960, p. 336 [**S. paracurvata;* OD]. Resembles *Globiella,* but with planoconvex deep corpus profile; outline more transverse, with recumbent, suberect spines on ventral valve, suberect spines on dorsal trail. *Upper Permian (Kazanian–Tatarian):* northeastern Russia.——Fig. 370,*3a–e. *S. paracurvata,* Kazanian,

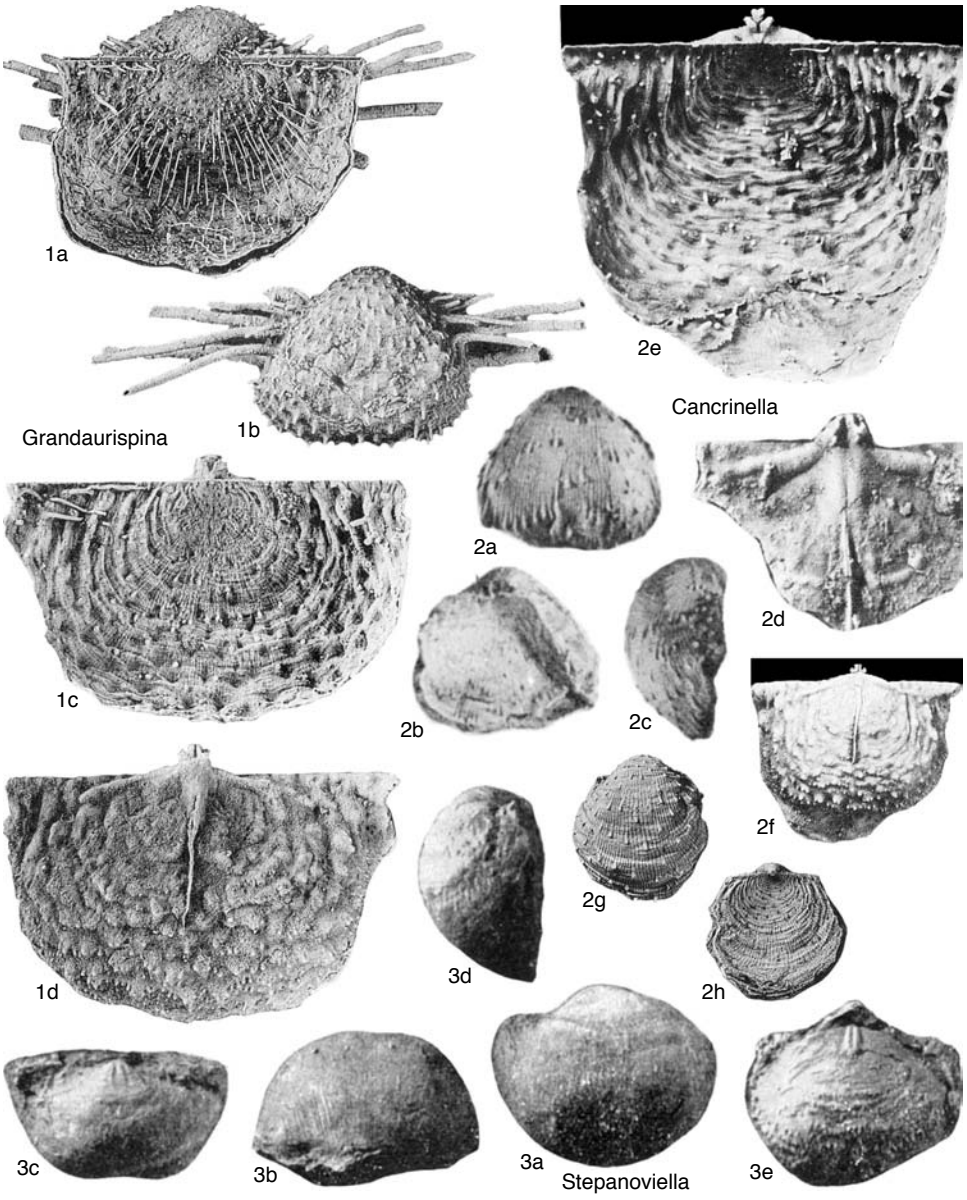

FIG. 370. Linoproductidae (p. 533–534).

Khivatch Horizon, Kolymo-Omolon; *a–d,* holotype, viewed ventrally, anteriorly, posteriorly, laterally, TsNIGRA 30/9081, ×1; *e,* dorsal valve interior, ×1 (Zavodowsky, 1960).

Terrakea BOOKER, 1930, p. 66 [**Productus brachythaerus* MORRIS in DE STREZELECKI, 1845, p. 284, *non* G. B. SOWERBY, 1844, p. 158; SD MAXWELL, 1956, p. 333] [=*Saetosina* WATERHOUSE in WATERHOUSE & BRIGGS, 1986, p. 54 (type, *Terrakea multispinosa* DEAR, 1971, p. 18)]. Medium size, gently concavoconvex profile, moderate to deep corpus; ribbing on both valves, ventrally with swollen elongate spine bases with semirecumbent spines; spines on dorsal valve mainly anteriorly; dorsal lateral ridges slightly divergent from hinge; median ridge commonly weakly divided posteriorly. *Lower Permian–lower Upper Permian:* eastern Australia, New Zealand, Russian Arctic.——FIG. 372,*2a–d.* **T. brachythaerum* (MORRIS), upper Marine Series, New South Wales; *a,* ventral valve internal mold viewed

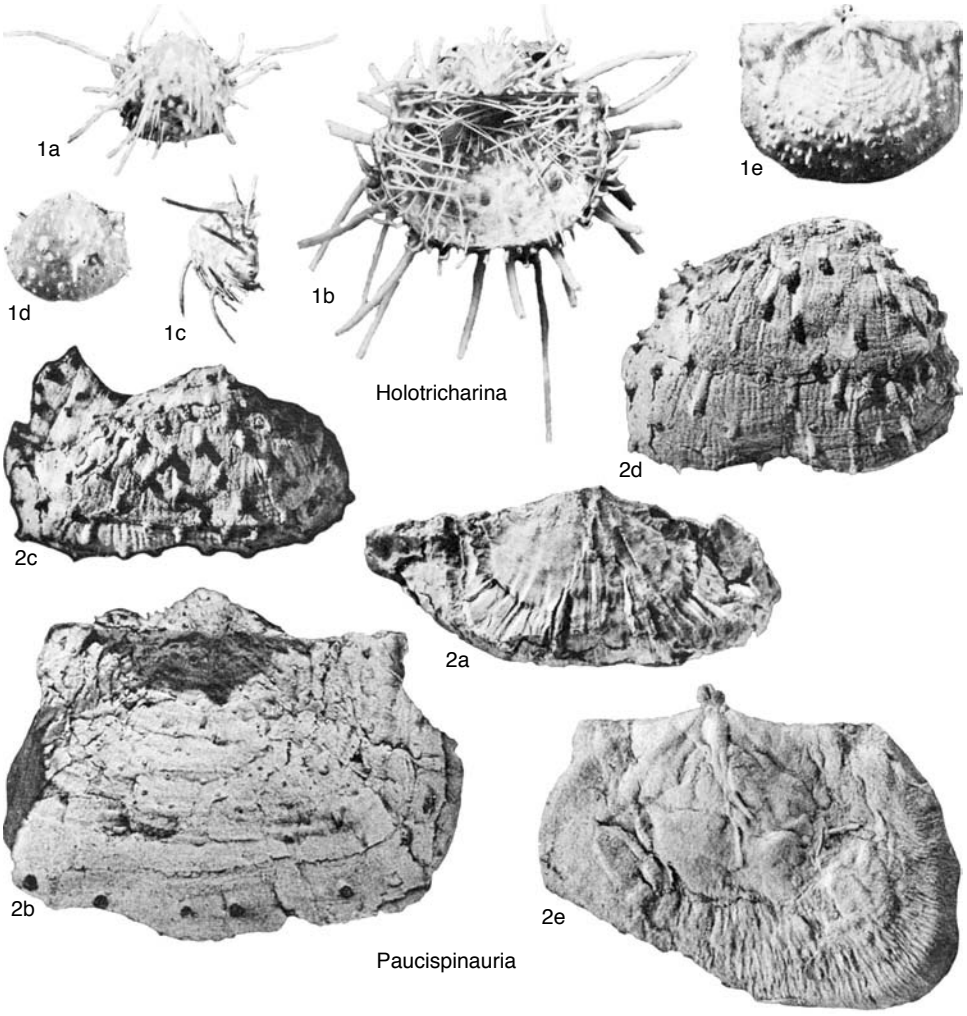

FIG. 371. Linoproductidae (p. 533).

laterally, ×1; *b,* exfoliated dorsal valve exterior, ×1; *c,* replica of shell viewed dorsally, ×1; *d,* replica of dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).——FIG. 372,*2e,f. T. fragile* (DANA); ventral valve internal mold, ventral valve exterior, ×1 (Muir-Wood & Cooper, 1960).

Subfamily SIPHONOSIINAE Lazarev, 1986

[Siphonosiinae LAZAREV, 1986c, p. 32]

Linoproductids with elongate outline, short tubiform ventral trail; hinge narrower than maximum width; spines rhizoid, on ventral valve only; marginal structures at borders of both valves. *upper Lower Permian (Artinskian–Kungurian).*

Siphonosia COOPER & GRANT, 1975, p. 1188 [**S. alleni;* OD]. Small siphonate shells; beak with small cicatrix; weakly reticulate disks; spines posterolaterally on ventral valve; ventral diductor scars widely triangular; cardinal process sessile, narrow quadrifid; lateral ridges strongly divergent; brachial ridges elongate, reaching disk borders. *upper Lower Permian (Artinskian–Kungurian):* USA.——FIG. 373*a–f. *S. alleni,* Cathedral Mountain Formation, Texas; *a–c,* holotype, ventral valve viewed ventrally, posteriorly, laterally, USNM 152789a, ×1.5; *d,* holotype, ventral valve viewed internally, USNM 152789a, ×1.5; *e,* dorsal valve exterior, ×2; *f,* dorsal valve interior, ×3 (Cooper & Grant, 1975).

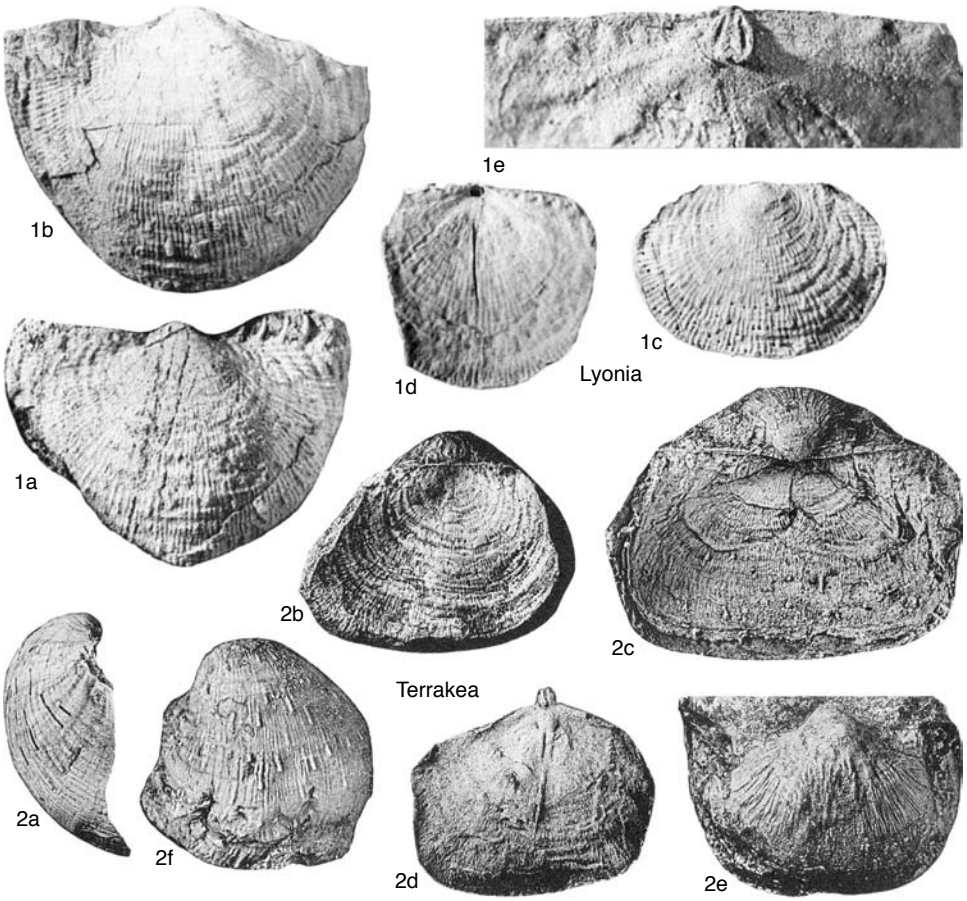

FIG. 372. Linoproductidae (p. 533–535).

Subfamily UNCERTAIN

Selloproductus TERMIER & others, 1974, p. 143 [**S. sellatus;* OD]. Poorly known elongate taxon with no information on characters of importance. Possibly a synonym of *Linoproductus*. *Upper Permian (Kazanian):* Afghanistan.

Family MONTICULIFERIDAE Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 929, *ex* Monticuliferinae MUIR-WOOD & COOPER, 1960, p. 327]

Linoproductoids with moderately shallow corpus cavity, rarely very shallow; rugae posterolaterally or irregularly widespread; spines on ventral valve, rarely restricted to hinge region; marginal structures normally absent. *Lower Devonian (Pragian)–Upper Permian (upper Tatarian).*

Subfamily MONTICULIFERINAE Muir-Wood & Cooper, 1960

[Monticuliferinae MUIR-WOOD & COOPER, 1960, p. 327]

Medium to large with weakly convex transverse profile; lateral shell profile flattened over disks, convex geniculation, trails; spines at hinge, scattered on venter; commonly with tubercles or monticules, capillae may be present. *Lower Permian (Artinskian)–Upper Permian (Kazanian).*

Monticulifera MUIR-WOOD & COOPER, 1960, p. 327 [**Productus intermedius* var. *sinensis* FRECH, 1911, p. 176; OD] [=*Sinoproductus* CHAN & LI, 1962, p. 477, obj.]. Medium size; monticules dense posteriorly, decreasing anteriorly, interrupted by irregular capillae; ill-defined ribs on trail; spines near hinge line, scattered on ventral valve; dorsal median septum narrow, almost reaching anterior edge of disk.

Lower Permian (Artinskian–Kungurian), Upper Permian (?Kazanian): central China, ?Indonesia.——Fig. 374,*2a–d. *M. sinensis* (Frech), Chihsian–Maokouan, Sichuan; *a,b,* ventral valve exterior, lateral views, ×1; *c,* detail of external ornament, ×3; *d,* incomplete dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Chilianshania Yang & Ting in Yang & others, 1962, p. 85 [**C. chilianshanensis* Ting in Yang & others, 1962, p. 86; OD] [=*Capillifera* Jin & Ye in Jin & others, 1979, p. 86, invalid; =*Pseudomonticulifera* Zhao & Tan, 1984b, p. 26 (type, *C. hunanensis* Zhao & Tan in Liu, Tan, & Ding, 1982, p. 189)]. Resembles *Monticulifera,* but lacks capillae ventrally and monticules; small spine tubercles present posteriorly. [*Capillifera* erected in incorrect belief that *Chilianshania* was junior homonym of a trilobite, however, spelling is different: *Qilianshania* Chu, 1960, p. 62.] *upper Lower Permian (Artinskian)–lower Upper Permian (Kazanian):* west central China.——Fig. 374,*1a–d. *C. chilianshanensis* (Ding), Chihsian–Maokouan, Qinghai; *a,b,* holotype, viewed posteriorly, anteriorly, IGAS 00178, ×1; *c,* ventral valve viewed posteroventrally, ×1; *d,* incomplete dorsal valve interior, ×1 (Yang & others, 1962).

?Paramonticulifera Tong, 1978, p. 234 [* *P. incosta;* OD] [=*Tongluella* Liang, 1990, p. 202[466] (type, *T. basilica*)]. Medium to large transverse shells, around 50 mm, resembling *Monticulifera,* but lacking capillae and having tuberculate ornament, possibly not true monticules; no anterior ribbing. *lower Upper Permian:* China.——Fig. 375,*1a–d. *P. incosta,* Upper Permian, Maokouan Formation, Sichuan; *a–c,* holotype, viewed ventrally, posteriorly, laterally, SB 4075, repository unknown, ×1; *d,* posterior view of ventral valve, ×1 (new).

Zhenania Ding in Zhang, Fu, & Ding, 1983, p. 293 [**Z. zhenanensis;* OD]. Poorly known; similar to *Monticulifera,* but with smaller tubercles or monticules; capillate, but with no anterior ribs. *upper Lower Permian (Roadian)–lower Upper Permian (Wordian):* China.——Fig. 375,*2a–c. *Z. zhenanensis,* Upper Permian, Shuixiakou Formation, Shanxi; posterior, anterior, lateral views, ×1 (Zhang, Fu, & Ding, 1983).

Subfamily AURICULISPININAE Waterhouse, 1986

[Auriculispininae Waterhouse in Waterhouse & Briggs, 1986, p. 57] [=Ovatiinae Lazarev, 1990, p. 121]

Medium size with rounded to elongate outline; spines normally on ventral valve only, with clusters on ears; teeth, sockets absent; marginal structures commonly absent. *Lower Carboniferous (Tournaisian)–Upper Permian (Capitanian).*

Auriculispina Waterhouse, 1975, p. 13 [**Cancrinella levis* Maxwell, 1964, p. 34; OD]. Medium size with narrow ventral umbo; both valves finely ribbed, moderately rugose; spines ventral only, dense along hinge, ears, quincuncially on venter; dorsal valve dimpled; ventral adductor scars smooth to striate. *Lower Permian:* eastern Australia.——Fig. 376,*1a–d. *A. levis* (Maxwell), Lower Permian, Burnett Formation, Yarrol basin; *a,* holotype, ventral valve internal mold, UQF 187056, ×1.5; *b,* incomplete ventral valve external mold, ×1.5 (Waterhouse & Briggs, 1986); *c,* dorsal valve internal mold, ×1.2; *d,* part of ventral valve exterior, ×1.2 (Maxwell, 1964).

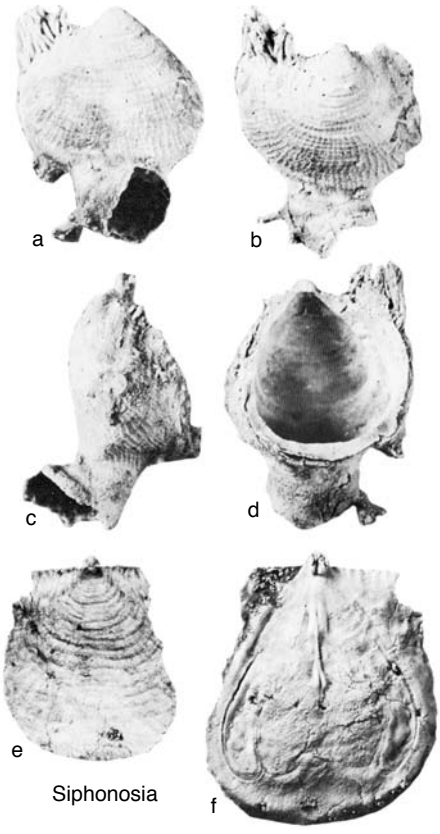

Fig. 373. Linoproductidae (p. 535).

Asperlinus Waterhouse & Piyasin, 1970, p. 132 [**Productus asperulus* Waagen, 1884, p. 693; OD]. Small size with relatively strong ribbing; spines evenly distributed over ventral valve, producing dorsal dimples; weak lateral ridges in dorsal valve. *upper Lower Permian–Upper Permian (Capitanian):* western Pakistan, Thailand, Timor.——Fig. 376,*4a–d. *A. asperulus* (Waagen), upper *Productus* Limestone, Capitanian, Salt Range, Pakistan; *a–c,* lectotype, viewed ventrally, dorsally, anteriorly, GSI F3732, ×1; *d,* incomplete dorsal valve interior, ×1 (Waagen, 1884).

Cancrinelloides Ustritsky in Ustritsky & Tschernjak, 1963, p. 85 [**Productus obrutschewi* Licharew,

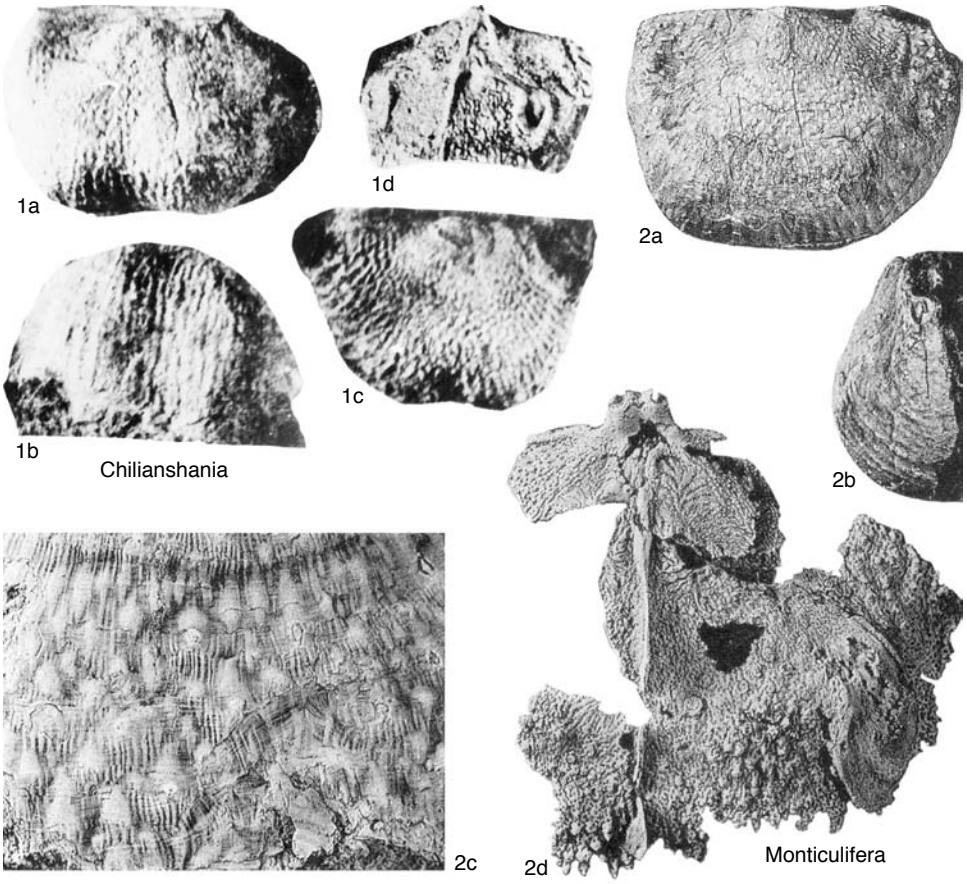

FIG. 374. Monticuliferidae (p. 536–537).

1934c, p. 24; OD]. Medium to large, transverse shell; profile gently convex with weak geniculation, short trail; corpus cavity becoming moderate in depth by adulthood; spine bases elongate except at hinge, anterior margin; spines evenly distributed, recumbent posteriorly, erect, more dense anteriorly; lateral ridges diverge from hinge, rather short; short ridges posterolaterally to dorsal adductor scars. *upper Lower Permian (Roadian):* Arctic, Transbaikalia, Mongolia.——FIG. 376,*3a–c. *C. obrutschewi* (LICHAREW), Roadian, Omolonskya; *a,* holotype, incomplete ventral valve exterior, TsNIGRA 16/10901, ×1; *b,* lateral view of ventral valve, ×1; *c,* ventral valve exterior, ×1 (Sarytcheva, 1977).

Chianella WATERHOUSE, 1975, p. 13 [**Avonia? chianensis* CHAO, 1927b, p. 126; OD] [=*Longyania* ZHU, 1990, p. 71 (type, *L. magna*)]. Small to medium shells with wide hinge, well-defined ears; ventral disk flattish, curving into simple trail; ribbing strong; spines along ventral hinge, sparsely scattered; rugae on dorsal flanks. [*Longyania* is very poorly known, appearing to be somewhat larger, coming from lower Upper Permian of China (Maokouan).] *upper Lower Permian (Kungurian)–lower Upper Permian (Kazanian):* China.——FIG. 377,*1a–c. *C. chianensis* (CHAO), Hsiaokiang Limestone, Jiangxi; *a,b,* holotype, viewed ventrally, laterally, NIGP 904, ×1; *c,* median longitudinal section of specimen, ×1 (Chao, 1927b).

Costatumulus WATERHOUSE in WATERHOUSE & BRIGGS, 1986, p. 58 [**Auriculispina tumidus* WATERHOUSE, BRIGGS, & PARFREY, 1983, p. 133; OD]. Similar to *Cancrinelloides* with double row of spines close to ventral hinge, but possibly with less regular rugae, elongate spine bases continuing to ventral valve margin. *Lower Permian (Artinskian):* Australia, central and ?eastern Himalayas.——FIG. 376,*2a–d. *C. tumidus* (WATERHOUSE, BRIGGS, & PARFREY), Lower Permian, Elvinia Formation, Bowen basin, Australia; *a,* replica of ventral valve exterior, ×1.5; *b,* replica of incomplete ventral valve exterior, ×1.5; *c,* dorsal valve external mold, ×1.5; *d,* replica of dorsal valve interior, ×1.5 (Waterhouse & Briggs, 1986).

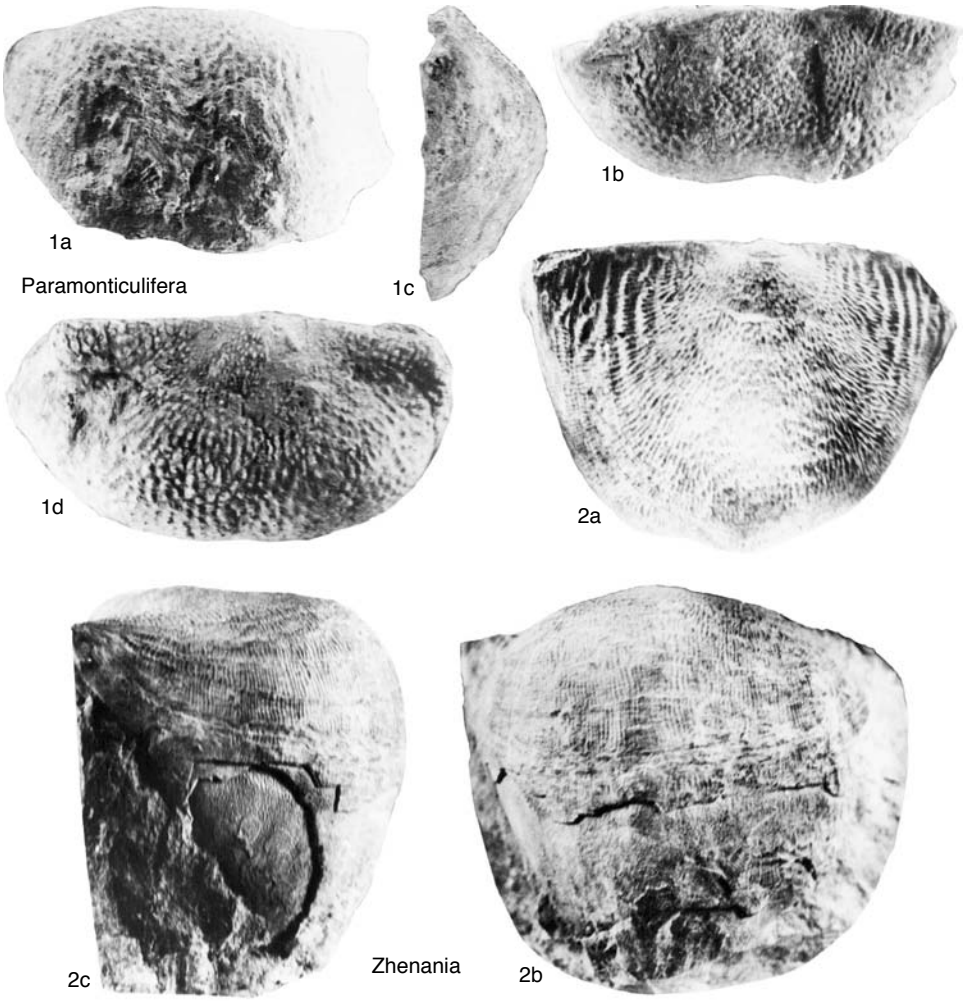

FIG. 375. Monticuliferidae (p. 537).

Filiconcha DEAR, 1969, p. 299 [**F. hillae;* OD]. Similar to *Cancrinelloides,* but with more abundant spines posteriorly, spines on dorsal valve also. *upper Lower Permian:* eastern Australia.——FIG. 377,*3a–e. *F. hillae,* Flat Top Formation, Lower Permian, Bowen basin, Australia; *a,* holotype, viewed ventrally, GSQ F10996a, ×1; *b,* replica of ventral valve exterior, ×1; *c,* dorsal valve internal mold, ×1.5; *d,* replica of part of dorsal interior, ×3; *e,* dorsal valve external mold, ×2 (Dear, 1969).

Globiella MUIR-WOOD & COOPER, 1960, p. 304 [**Productus hemisphaerium* KUTORGA, 1844, p. 99; OD]. Smaller medium size shell, globose, anteriorly elongate; small, poorly differentiated ears at maximum width; anterior flanks steep, corpus cavity moderately shallow; ribbing fine, regular, covering shell; spines only at ventral hinge; ventral muscle field deeply impressed; ventral lateral ridges separate ears, fit with weak dorsal ridges; paired median ridges separate dorsal adductor fields. *Upper Permian (Kazanian):* Russia, Himalayan chain.——FIG. 377,*2a–g. *G. hemisphaerium* (KUTORGA), Kazanian, Kama River, Russia; *a–c,* ventral valve viewed ventrally, laterally, internally, ×1; *d,* dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960); *e,f,* shell viewed ventrally, dorsally, ×1; *g,* posterior view of shell, ×1 (Grigorjewa, 1962).

Linoprotonia FERGUSON, 1971, p. 551 [**Productus hemisphaericus* J. SOWERBY, 1822 in 1821–1822, p. 31; OD] [=*Connectoproductus* DONAKOVA, 1974, p. 173 (type, *Productus probus* ROTAI, 1931, p. 53]. Size medium to large; gently concavoconvex profile,

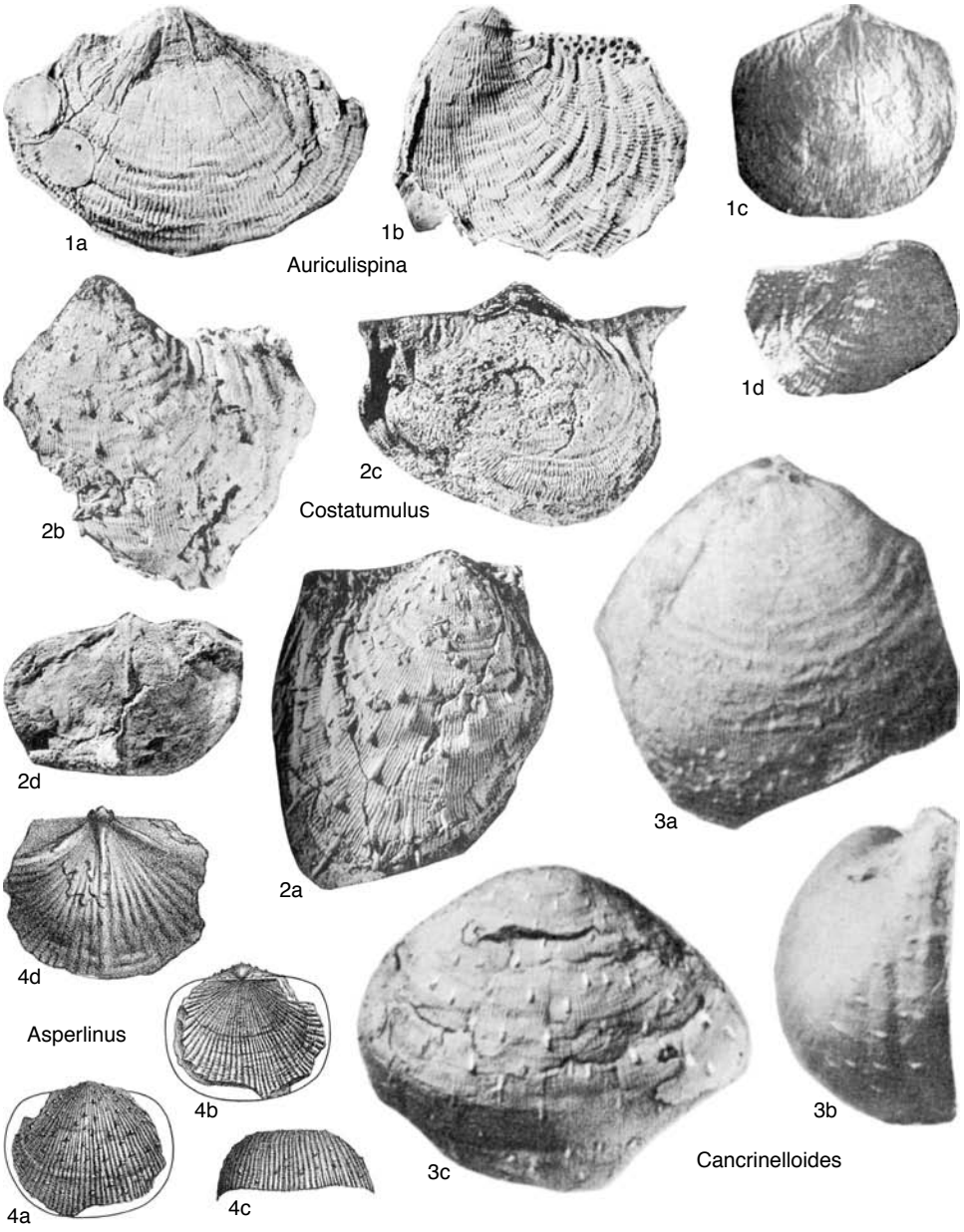

FIG. 376. Monticuliferidae (p. 537–538).

umbo weakly differentiated; rugae weakly developed; low cardinal process, commonly with pit; brachial cones low. *Lower Carboniferous (upper Tournaisian–Viséan):* Eurasia, northern Africa.—— FIG. 378,*1a–e.* **L. hemisphaericus* (J. SOWERBY), Asbian; *a,* lectotype, viewed ventrally, southern Wales, BMNH B 44114, selected by PRENTICE, 1949, p. 265, ×1; *b,* dorsal valve exterior, southern Wales, ×1; *c,* ventral valve internal mold, Somerset, ×1; *d,* incomplete dorsal valve interior, northern Wales, ×1; *e,* details of posterolateral spines on ventral valve, Lancashire, ×3 (new).

Liraria COOPER & GRANT, 1975, p. 1156 [*L. lirata;* OD]. Resembles *Globiella,* but wider than long;

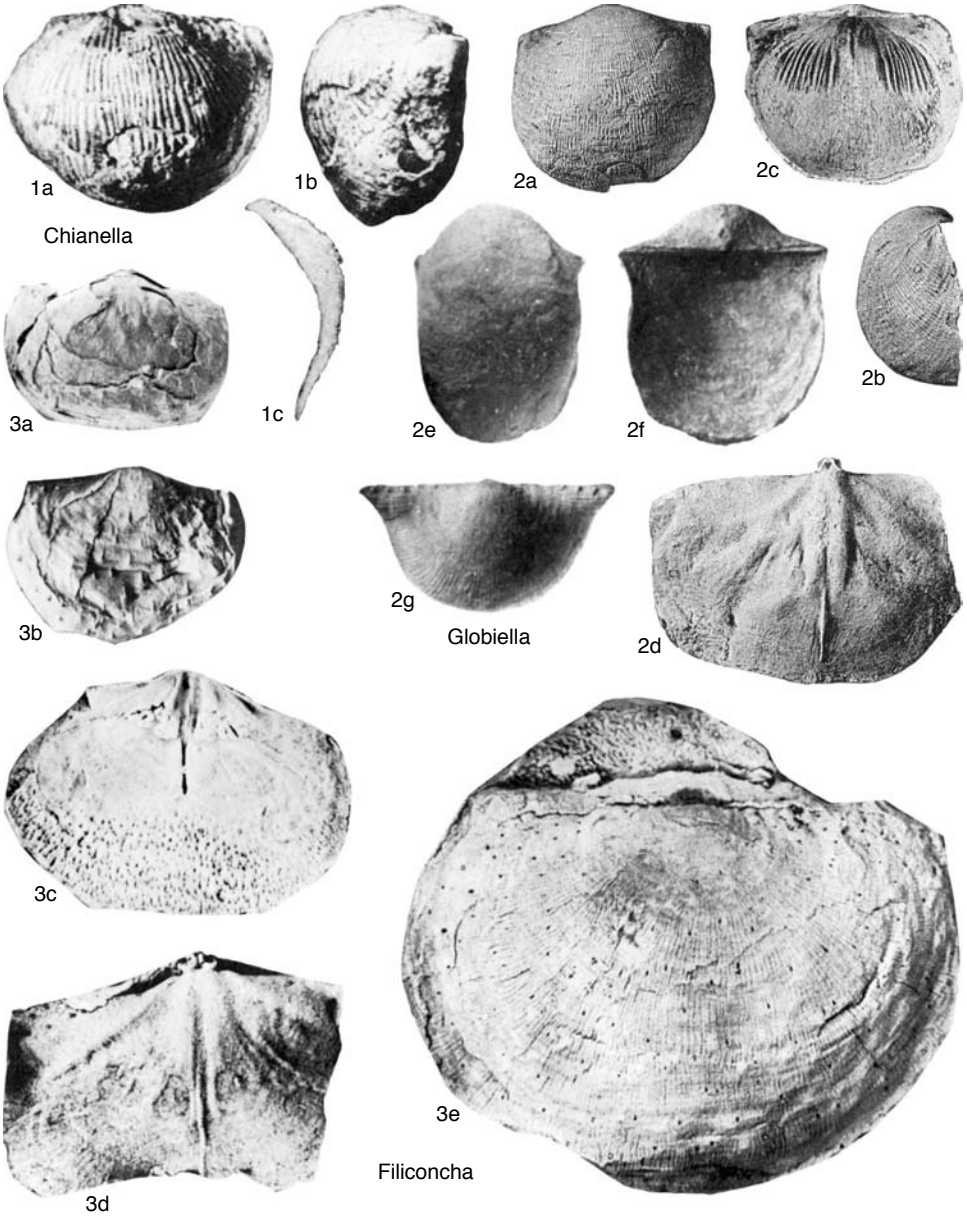

FIG. 377. Monticuliferidae (p. 538–539).

spines near hinge, few on venter; dorsal median septum more prominent; dorsal lateral ridges short, strong, divergent; adductor scars with raised median edges. *Lower Permian (Artinskian–Kungurian):* USA.——FIG. 378,*3a–f.* **L. lirata,* Bone Spring Formation, Texas; *a–d,* holotype, viewed ventrally, posteriorly, laterally, internally, USNM 152782a, ×1; *e,* dorsal valve exterior, ×2; *f,* dorsal valve interior, ×3 (Cooper & Grant, 1975).

Magadania GANELIN in GRIGORJEWA, GANELIN, & KOTLYAR, 1977, p. 153 [**Cancrinella? bajkurica* USTRITSKY in USTRITSKY & TSCHERNJAK, 1963, p. 65; OD]. Outline elongate, stongly concavoconvex with shallow corpus cavity; ribbing narrow, rugae on dorsal disk; spines only ventrally, elongate, slightly swollen bases, recumbent, becoming erect anteriorly; dorsal lateral ridges strongly divergent from hinge; median septum divided posteriorly; shell

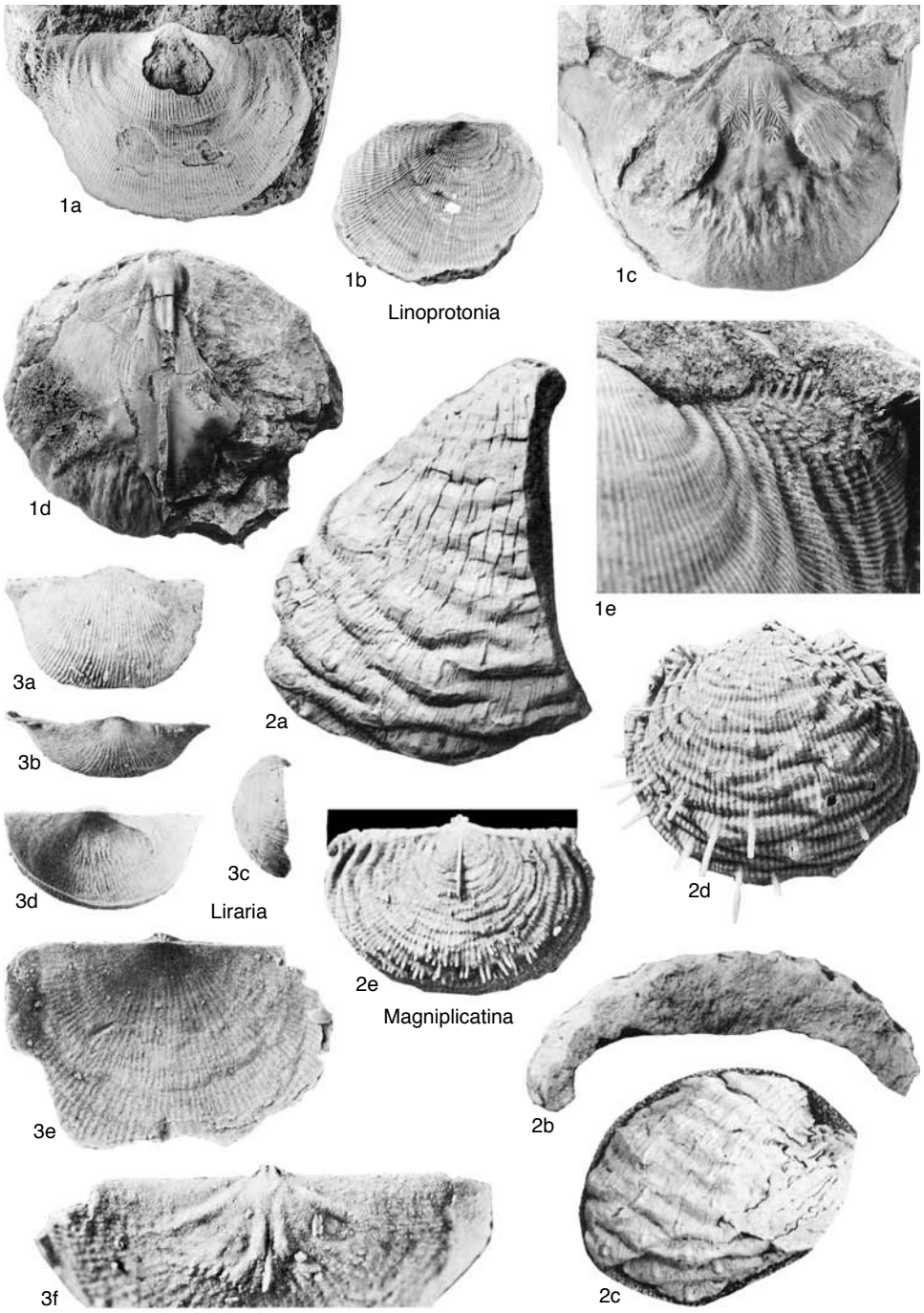

FIG. 378. Monticuliferidae (p. 539–544).

walls thick. *Upper Permian (?Kazanian):* Taymyr, ?northeastern Mongolia.——Fig. 379,*1a–d.* **M. bajkurica* (USTRITSKY), Upper Permian, upper Baykur Formation, River Sokolinaya, Russia; *a,b,* holotype, viewed ventrally, dorsally, TsNIGRA 126/8263, ×2; *c,* ventral valve internal mold, ×1

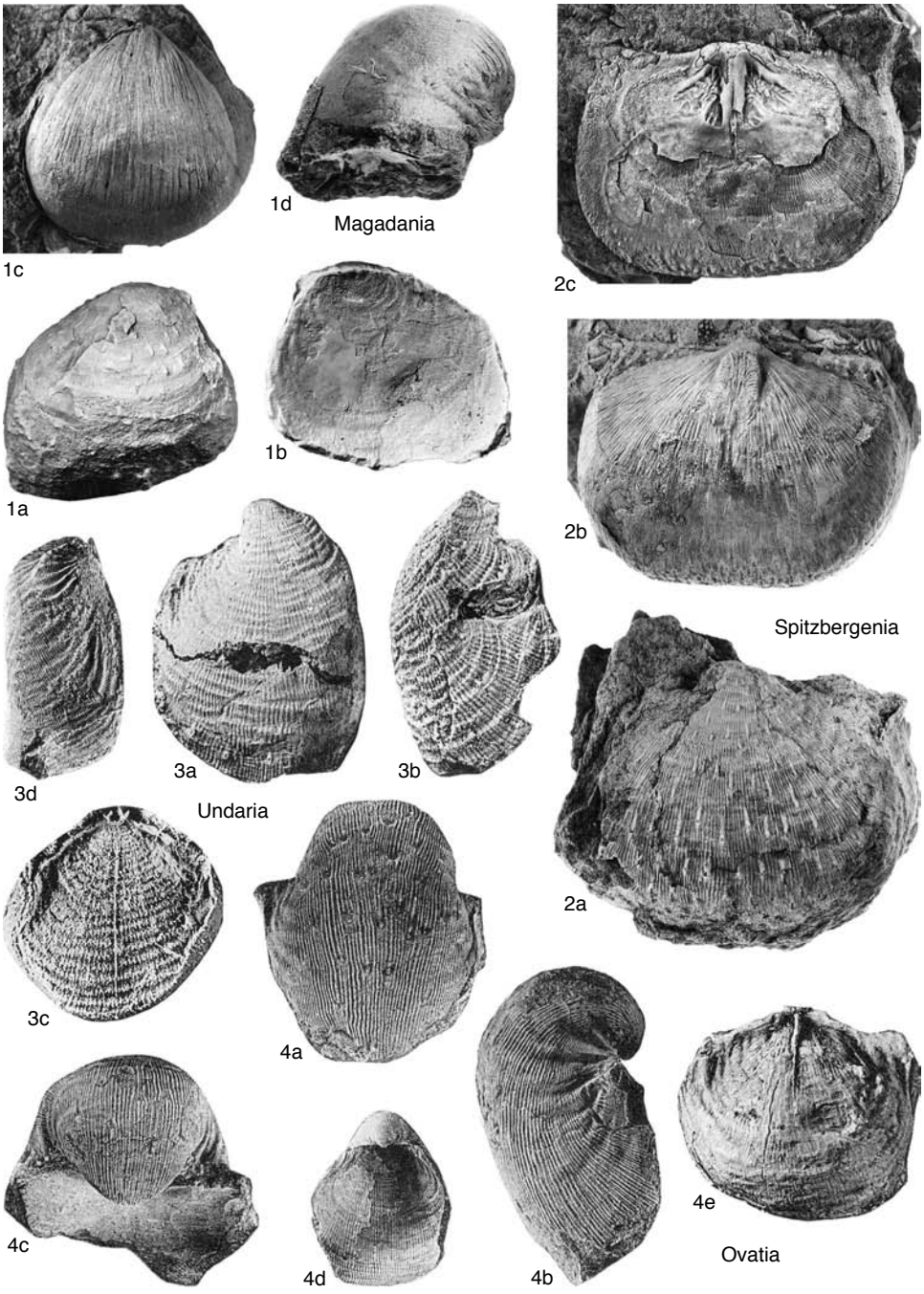

FIG. 379. Monticuliferidae (p. 541–546).

(Grigorjewa, Ganelin, & Kotlyar, 1977); *d,* ventral valve viewed laterally, ×1 (new).

Magniplicatina WATERHOUSE, 1983b, p. 130 [**Cancrinella magniplica* CAMPBELL, 1953, p. 7; OD] [=*Helenaeproductus* LAZAREV in PAVLOVA & others, 1991, p. 117 (type, *H. khubsugulensis*)]. Resembles *Cancrinella,* but with shallow corpus, strong rugae on ventral valve and relatively thick, widely

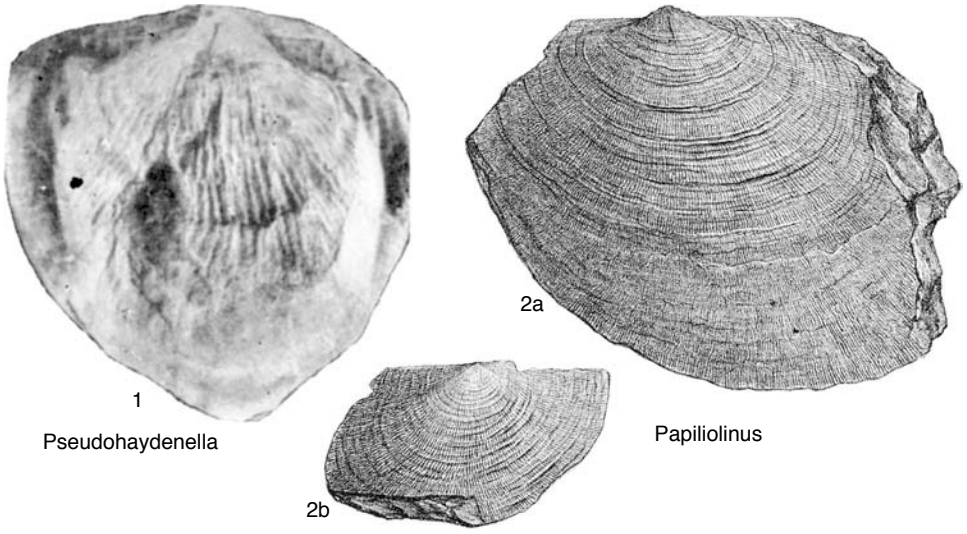

FIG. 380. Monticuliferidae (p. 544).

spaced ventral spines. *upper Lower Permian (Kungurian)–Upper Permian (Kazanian):* Australia, New Zealand, USA, Mongolia, Russian Arctic, ?China.——FIG. 378,*2a–c. M. halli* (WATERHOUSE), Mangarewa Formation, New Zealand; *a,b,* holotype, ventral, lateral views of incomplete internal mold, NZGS BR950, ×1; *c,* oblique view of ventral valve internal mold, ×1 (Waterhouse, 1982c).——FIG. 378,*2d,e. M. sparsispinosa* (COOPER & GRANT), Bone Spring Formation, Texas; *d,* holotype, ventral valve exterior, USNM 152780a, ×2; *e,* dorsal valve interior, ×2 (Cooper & Grant, 1975).

Ovatia MUIR-WOOD & COOPER, 1960, p. 311 [**O. elongata;* OD]. Small to medium sized; ventral profile close to ideal spiral with no geniculation, trail narrow, elongate; umbo narrow, but highly arched, strongly differentiated from ears where rugae are strong; one to two rows of spines near hinge, sparsely scattered on ventral valve where they commonly interrupt ribs; lateral ridges short. *Lower Carboniferous (Tournaisian)–Upper Carboniferous (Serpukhovian):* North America, Eurasia, northern Africa.——FIG. 379,*4a–e. *O. elongata,* Chesterian, Oklahoma; *a–c,* holotype, viewed anteroventrally, laterally, posteriorly, USNM 124101a, ×1; *d,* dorsal view of small shell, ×1; *e,* dorsal valve interior, ×1 (Muir-Wood & Cooper, 1960).

Papiliolinus WATERHOUSE & GUPTA, 1977, p. 160 [**P. eishmakami;* OD, *nom. nov. pro Productus undatus* DIENER, 1899, p. 23, *non* DEFRANCE, 1826]. Poorly known; large; subsemicircular outline, profile curvature weak; ribbing fine for family, rugae fine and possibly covering valves; cardinal process seemingly trifid with broad median ridge. *upper Lower Carboniferous (upper Viséan):* northern India.——FIG. 380,*2a,b. *P. eishmakami,* upper Viséan, Kashmir; two external casts of dorsal valves, ×1 (Diener, 1899).

Pseudohaydenella LIANG, 1990, p. 174[462] [**P. huadongensis;* OD] [=*Lamiproductus* LIANG, 1990, p. 205[467] (type, *L. typicus*)]. Poorly known, possible synonym of *Chianella.* Medium to large, subtriangular, somewhat nasute outline; no sulcus; rugae confined to ears; spines sparsely scattered on ribs; dorsal lateral ridges low, thick. *Upper Permian (upper Capitanian):* eastern China.——FIG. 380,*1. *P. huadongensis,* upper Capitanian, Lengwu Formation, Zhejiang; ventral valve exterior, ×1.5 (Liang, 1990).

Spitzbergenia G. KOTLYAR in GRIGORJEWA, GANELIN, & KOTLYAR, 1977, p. 155 [**Productus loveni* WIMAN, 1914, p. 72; OD]. Medium, subquadrate outline; prominent elongate spine bases on ventral disk resemble *Magniplicatina,* but lacks prominent rugae; spines recumbent, thin, concentric arrangement anteriorly, erect spines on ears, flanks, trail; ventral diductor scars enclose adductor scars anteriorly; cardinal process small, supported by medianly grooved median septum, strongly diverging short lateral ridges. *lower Upper Permian (Kazanian):* Spitzbergen, Novaya Zemlaya, Canada, Alaska, northern and northeastern European Russia.——FIG. 379,*2a–c. *S. loveni,* Kazanian, Selander Formation, Spitzbergen; *a,* ventral valve exterior, ×1; *b,* ventral valve internal mold, ×1; *c,* dorsal valve interior, ×1 (Grigorjewa, Ganelin, & Kotlyar, 1977).

Teleoproductus LI LI in LI LI, YANG DE-LI, & FENG RU-LIN, 1986, p. 230 [**T. typicus;* OD]. Small to medium size, hinge widest part of shell, anterior margin strongly nasute, but not forming tube with dorsal trail; rugae strong on flanks, ears, dorsal disk; spines at hinge and few on ventral flanks; interiors unknown. *Lower Permian (Sakmarian)–lower Upper Permian (Wordian):* China.——FIG. 381,*3a–c. *T. typicus,* Longyin Formation, Guangxi; holotype,

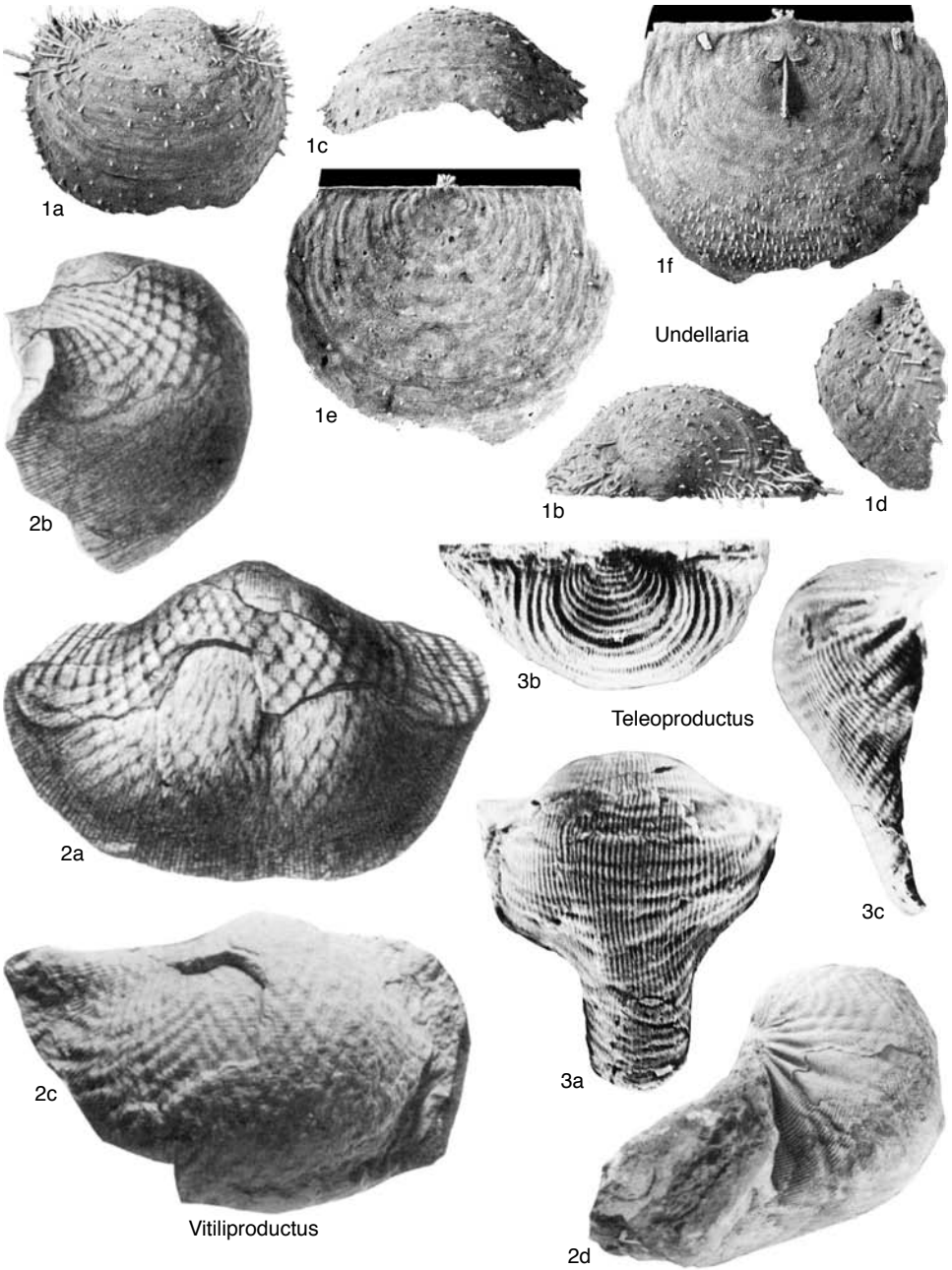

FIG. 381. Monticuliferidae (p. 544–546).

viewed anteroventrally, posteriorly, laterally, ?NGM 562176 (repository unknown), ×1.5 (new).

Undaria MUIR-WOOD & COOPER, 1960, p. 317 [**U. manxensis;* OD]. Small; trails elongate, tubiform; ribbing entire, prominent at rugae that cover corpus, trails posteriorly; spines at and close to hinge, widely scattered on ventral corpus; cardinal process bilobed, quadrifid; lateral ridges and short ear baffles, median septum long, but thin. *upper Lower Carboniferous (upper Viséan):* western Europe.——FIG. 379,*3a–c. *U. manxensis,* Asbian, Isle of Man; *a,* incomplete ventral valve exterior, ×2; *b,* external

mold of dorsal valve viewed laterally, ×2; *c,* replica of dorsal valve interior, ×3 (Muir-Wood & Cooper, 1960).——Fig. 379,*3d. U. erminea* (de Koninck), Viséan, Belgium; external mold of dorsal valve viewed laterally, ×1 (Muir-Wood & Cooper, 1960).

Undellaria Cooper & Grant, 1975, p. 1157 [**U. magnifica;* OD]. Medium size with hinge slightly narrower than midwidth; transverse profile evenly convex; rugae weak on both valves; spines numerous, thin, short, less abundant on anterior venter; ventral muscle field relatively small; cardinal process small, sessile, bilobed, quadrifid; lateral ridges weak, short in both valves; adductor scars raised anteriorly. *upper Lower Permian (Artinskian–Kungurian):* USA.——Fig. 381,*1a–f.* **U. magnifica,* Bone Spring Formation, Texas; *a–d,* holotype, viewed ventrally, posteriorly, anteriorly, laterally, USNM 152783b, ×1; *e,f,* dorsal valve exterior, interior, ×1.5 (Cooper & Grant, 1975).

?Vitiliproductus Ching Yu-gan & Liao Zhao-ting, 1974, p. 278 [**Productus groeberi* Krenkel, 1913, p. 42; OD]. Medium to large; intersecting oblique rugae forming tetrahedral elevations over corpus, rugae commonly strong at flanks; interiors unknown. *Lower Carboniferous (upper Viséan):* China, western Europe, Asia, Australia.——Fig. 381,*2a–c.* **V. groeberi* (Krenkel); *a,b,* ventral, lateral views of shell, as figured by Krenkel (1913), ?Asbian, Tien Shan, ×1; *c,* ventral valve exterior, upper Viséan, Guizhou, ×1 (Brunton & Mundy, 1988a).——Fig. 381,*2d. V. wedberensis* Brunton & Mundy, ?Asbian, Kerry County, Ireland; lateral view of ventral valve, ×1 (Brunton & Mundy, 1988a).

Subfamily COMPRESSOPRODUCTINAE Jing & Hu, 1978

[Compressoproductinae Jing & Hu, 1978, p. 115]

Small or medium size, elongate outline, hinge narrow; corpus cavity moderately shallow; valves thin shelled with complete ribbing, rugae; spines rare, rhizoid; cardinal process single median ridge (unifid), lateral ridges weak. *Lower Permian–Upper Permian (upper Tatarian).*

Compressoproductus Sarytcheva in Sarytcheva, Licharew, & Sokolskaja, 1960, p. 231 [**Productus compressus* Waagen, 1884, p. 710; OD] [=*Substriatifera* Kotlyar, 1964, p. 123 (type, *Productus (mytiloides) vladivostockensis* Fredericks, 1925, p. 17)]. Medium size, elongate trigonal outline resembling *Stratifera,* but commonly with narrow hinge, deeper corpus cavity, and rugae persisting over both valves; ventral lateral ridges weak; shell substance thin. *Upper Permian (Kazanian–upper Tatarian):* Pakistan, northern Caucasus, Transcaucasus, southeastern Asia.——Fig. 382,*1a–c.* **C. compressus* (Waagen), *Productus* Limestone, Salt Range, Pakistan; ventral valve exterior viewed ventrally and from both sides, ×0.8 (Waagen, 1884).

Fallaxoproductus Li, Gu, & Li, 1982, p. 115[128] [**F. sutungensis;* OD]. Resembles *Compressoproductus,* but lacks ears and rugae confined to dorsal valve. *Lower Permian:* Inner Mongolia.——Fig. 382,*2a.* **F. sutungensis,* Lower Permian, Inner Mongolia; ventral valve exterior, ×1 (Li, Gu, & Li, 1982).——Fig. 382,*2b–d. F. dedorus,* Lower Permian, Inner Mongolia; *b,* dorsal valve exterior, ×1; *c,d,* internal molds of ventral, dorsal valves, ×1 (Li, Gu, & Li, 1982).

Sarytchevinella Waterhouse, 1983a, p. 126 [**Productus djulfensis* Stoyanow, 1915, p. 84; OD]. Resembles *Compressoproductus,* but may differ in having somewhat wider hinge line, in having spines on the venter, and weak or no rugae anteriorly. *Upper Permian (upper Capitanian):* Armenia, Caucasus, southern China, northern Thailand.——Fig. 382,*3a–c.* **S. djulfensis* (Stoyanow), upper Capitanian, Armenia; *a,b,* exterior viewed ventrally, laterally, ×1; *c,* posterior part of shell viewed dorsally, ×2 (Stoyanow, 1915).

Subfamily DEVONOPRODUCTINAE Muir-Wood & Cooper, 1960

[Devonoproductinae Muir-Wood & Cooper, 1960, p. 177]

Moderately shallow corpus cavity; fine ribbing especially on ventral valve; dorsal valves with concentric lamellae as traces of series of trails; cardinal process pit absent; ear baffles in ventral valve, weak dorsal lateral ridges; weak submarginal ridge in dorsal valve with papillae. *Middle Devonian (Eifelian)–Upper Devonian (Frasnian).*

Devonoproductus Stainbrook, 1943, p. 55 [**Productella walcotti* Fenton & Fenton, 1924, p. 119; OD, *nom. nov. pro Productus dissimilis* Hall, 1858a, p. 497, *non* de Koninck, 1847a, p. 225; =*P. (Productella) hallana* Walcott, 1884, p. 130, *partim*] [=*Striatoproductus* Nalivkin, 1947, p. 75 (type, *Orthis sericea* von Buch, 1838, p. 68)]. Small; outline subcircular, cicatrix small, rare; spines suberect at hinge, widely scattered ventrally from bases wider than ribs; dorsal lamellae prominent; lateral ridges may continue anteriorly; median septum long, not supporting cardinal process. *Upper Devonian (Frasnian):* North America, Europe, central Asia.——Fig. 383,*1a–f.* **D. walcotti* (Fenton & Fenton), Frasnian, Iowa; *a,b,* shell viewed posteriorly, laterally, ×2; *c,* ventral valve exterior, ×2; *d,* ventral valve interior, ×2; *e,f,* dorsal valve exterior, interior, ×3 (Muir-Wood & Cooper, 1960).

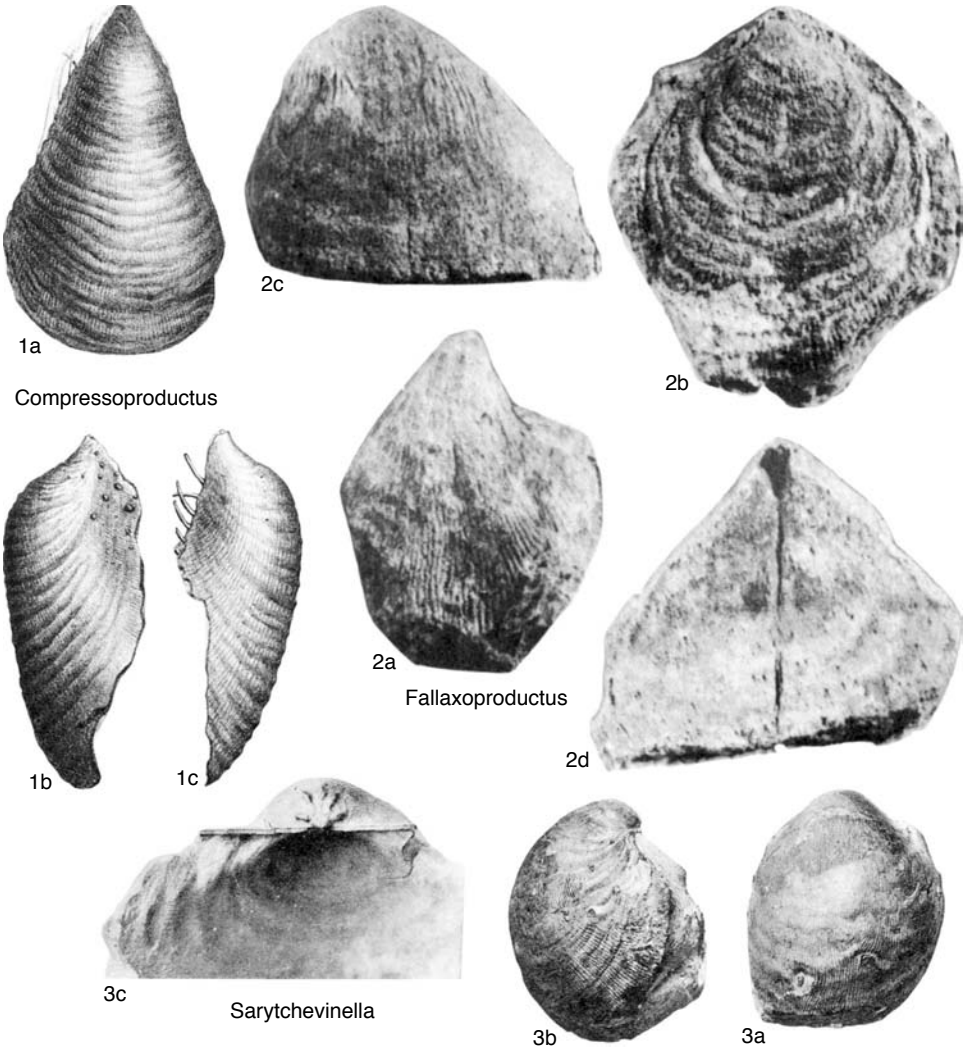

FIG. 382. Monticuliferidae (p. 546).

Chonopectoides CRICKMAY, 1963, p. 23 [**C. catamorphus;* OD]. Poorly known; small, around 4.5 mm wide, chonetiform shells with ventral ginglymus; ribs fine, obscure, on ventral valve only; dorsal valve lamellose; spines project posterolaterally from hinge only; teeth strong; socket ridges continue as weak ear baffles. *upper Middle Devonian:* Canada (Northwest Territories).——FIG. 383,*2a–d.* **C. catamorphus; a,* holotype, viewed ventrally, PRI 27124, ×10; *b,* ventral valve interior, ×10; *c,* dorsal valve exterior, ×10; *d,* dorsal valve interior, ×10 (new).

Poloniproductus BIERNAT & LAZAREV, 1988, p. 66 [**Productella varians* BIERNAT, 1966, p. 66; OD]. Resembles *Devonoproductus,* but with suberect spines from slightly elongate bases and weak concentric lamellae on both valves; no ribbing; teeth small; brachial impressions wide on disk. *Middle Devonian (Eifelian):* eastern Europe.——FIG. 383,*3a–f.* **P. varians* (BIERNAT), Eifelian, Holy Cross Mountains; *a–c,* shell viewed ventrally, posteriorly, laterally, ×2 (new); *d,* shell viewed dorsally, ×2 (Lazarev, 1990); *e,* ventral valve interior, ×2 (new); *f,* dorsal valve interior, ×2.5 (Biernat, 1966).

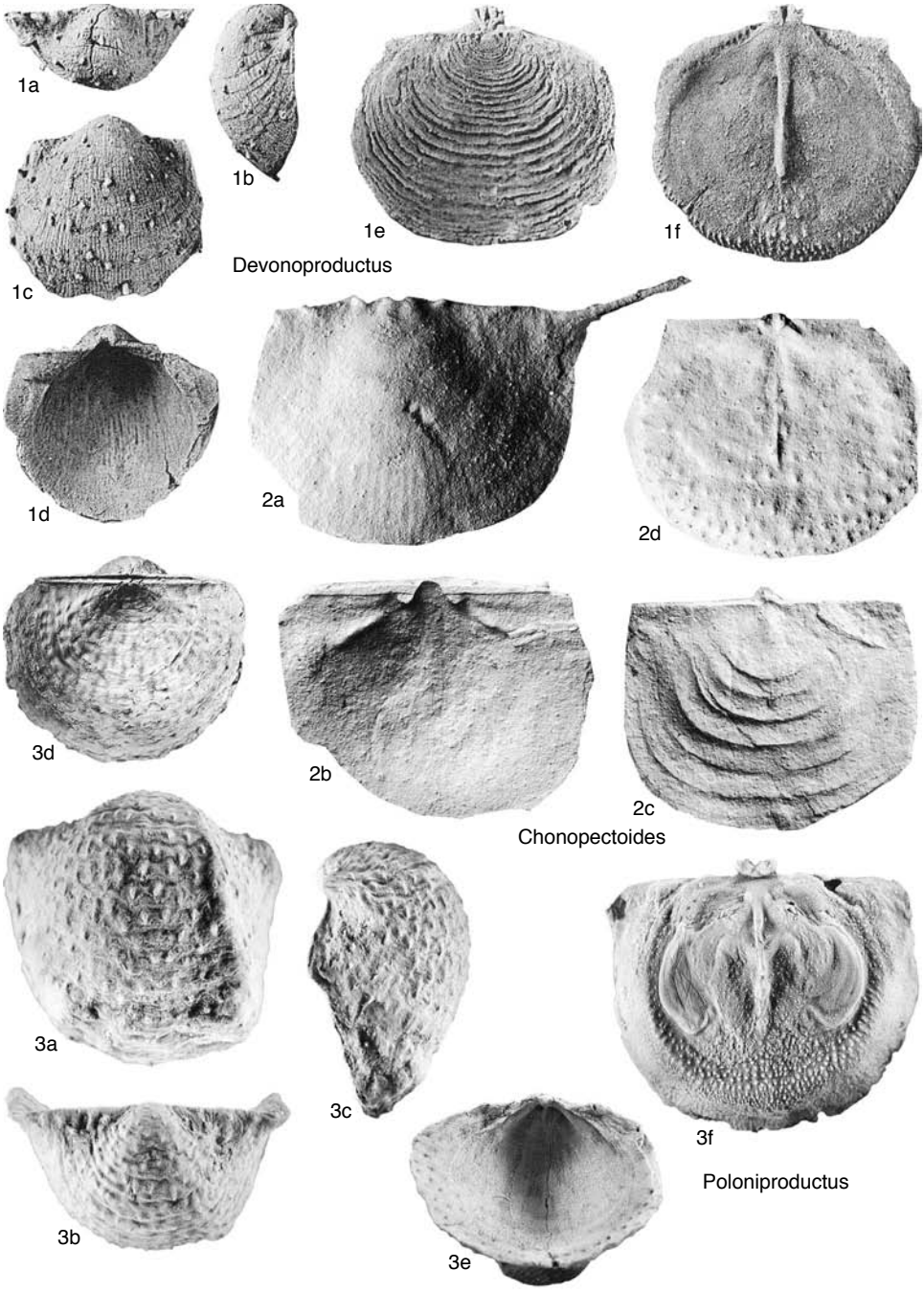

FIG. 383. Monticuliferidae (p. 546–547).

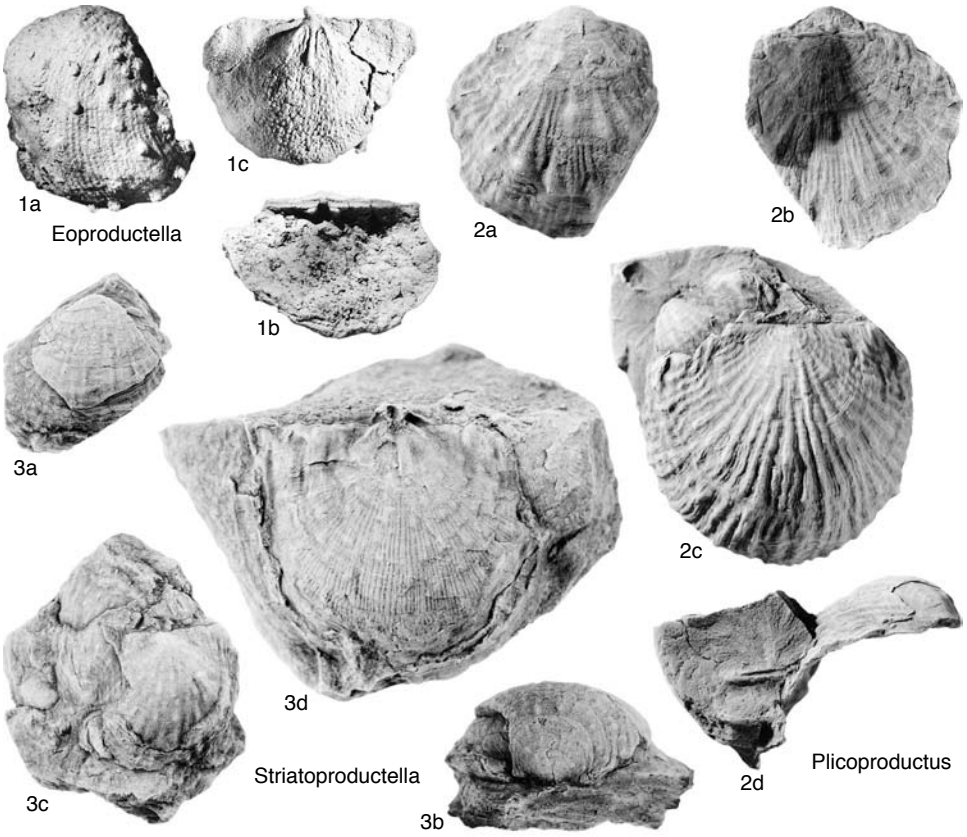

FIG. 384. Monticuliferidae (p. 549–550).

Subfamily EOPRODUCTELLINAE Lazarev, 1987

[Eoproductellinae LAZAREV, 1987, p. 49]

Small or medium size; both valves or dorsal valve only with fine ribbing, spines on ventral valve only; teeth, sockets present. *Lower Devonian (Pragian)–Middle Devonian (upper Givetian).*

Eoproductella RZHONSNITZKAYA, 1980, p. 59 [**E. menakovae;* OD]. Small; hinge widest part of shell; profile strongly concavoconvex; ribbing weak on both valves, spines widespread from thick bases; anderidia present. *Lower Devonian (Pragian–Emsian):* middle Asia.——FIG. 384,*1a–c.* **E. menakovae,* Pragian, Tadjikistan; *a,* oblique lateral view of ventral valve, ×1; *b,* ventral valve viewed dorsally showing teeth, ×1.5; *c,* dorsal valve interior, one lobe of cardinal process missing, ×1.5 (Lazarev, 1990).

Plicoproductus LJASCHENKO, 1969, p. 14 [**Productella mosolovica* LJASCHENKO, 1958a, p. 93; OD]. Small; relatively coarsely costellate with additional fine striae especially dorsally; spines ventral, relatively coarse with irregular concentric arrangement. *Middle Devonian (Eifelian):* Russia.——FIG. 384,*2a–d.* **P. mosolovica* (LJASCHENKO), Middle Devonian, Russia; *a,b,* ventral, dorsal views of shell, ×2; *c,d,* dorsal valve external mold, lateral view of shell with two spines, ×2 (new).

Striatoproductella KRYLOVA, 1962, p. 54 [**Striatoproductus tunguensis* NALIVKIN, 1960, p. 319; OD] [=*Hanaeproductus* FICNER & HAVLÍČEK, 1978, p. 65 (type, *Productus rittbergensis* QUENSTEDT, 1871, p. 613)]. Small with subcircular corpus; spine bases fine, elongate, only ventrally; dorsal valve with low

FIG. 385. Monticuliferidae (p. 551).

dichotomizing ribs; teeth small. *Middle Devonian (upper Givetian):* northern Eurasia.——FIG. 384,*3a–d. *S. tunguensis* (NALIVKIN), upper Givetian, Siberia; *a,* ventral valve exterior viewed ventrally, ×1; *b,* ventral valve exterior viewed posteriorly, ×1.5; *c,* dorsal valve external mold, ×1; *d,* partly exfoliated dorsal valve interior, ×2 (new).

Subfamily GIGANTOPRODUCTINAE Muir-Wood & Cooper, 1960

[Gigantoproductinae MUIR-WOOD & COOPER, 1960, p. 330]

Gigantic, large or medium size, hinge at greatest width; corpus cavity very shallow;

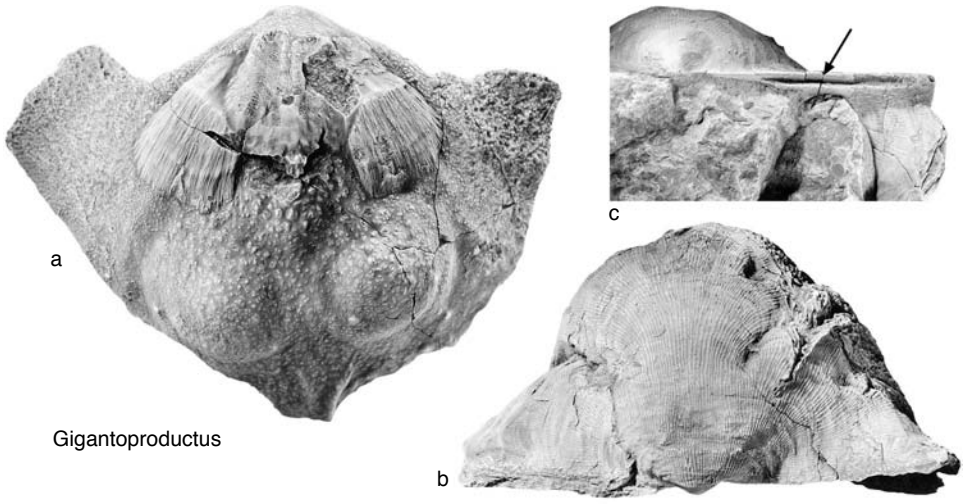

FIG. 386. Monticuliferidae (p. 551).

fully ribbed, spines on ventral valve, rarely also on dorsal valves; marginal structures commonly absent; cardinal process pit commonly present. *Lower Carboniferous (Viséan)–Upper Carboniferous (Serpukhovian).*

Tribe GIGANTOPRODUCTINI Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 930, *ex* Gigantoproductinae MUIR-WOOD & COOPER, 1960, p. 330] [=*Kansuellinae* MUIR-WOOD & COOPER, 1960, p. 336]

Large or gigantic, thick-walled ventral valves; ventral umbo not strongly incurved; commonly ribbed; spines commonly on ventral valve; cardinal process trifid with median ridge well developed or sole element; brachial cones commonly distinct. *Lower Carboniferous (Viséan)–Upper Carboniferous (Serpukhovian).*

Gigantoproductus PRENTICE, 1950, p. 437, *nom. nov. pro Gigantella* SARYTCHEVA, 1928, p. 13, *non* EKMAN, 1905 [**Anomites giganteus* MARTIN, 1793, pl. 15, fig. 1 (invalid, ICZN, 1950); =*Productus giganteus* J. SOWERBY, 1822 in 1821–1822, p. 19; SD MUIR-WOOD, 1951, p. 98 (species validated and SD confirmed, ICZN, 1956b, Opinion 420, p. 135)]. Commonly gigantic, transverse; ribbing entire, but commonly irregular and weakened at trail plications; spines rare; ventral valve thick-shelled with pits accommodating dorsal brachial cones; cardinal process trifid, sessile. *Lower Carboniferous (upper Viséan):* Eurasia, northern Africa.——FIG. 385*a–c.* **G. giganteus* (J. SOWERBY), upper Viséan; *a,* ventral valve exterior, England, ×0.6 (Muir-Wood, 1965b); *b,c,* incomplete dorsal valve interior, internal mold, northern Wales, ×1 (new).——FIG. 386*a–c.* **G. giganteus* (J. SOWERBY), upper Viséan; *a,* ventral valve internal mold, northern Wales, ×0.6; *b,c,* ventral valve viewed posteriorly, showing damaged shell, and dorsally showing short ginglymus (*arrow*), Scotland, ×0.5 (new).

Beleutella LITVINOVICH, 1967, p. 55 [**B. rara;* OD]. Outline subrounded; ventral profile flattened umbonally; ginglymus strongly developed; ribbing narrow; spines thin, sparse; valve walls thick; cardinal process prominent, trifid with fused median ridges dominant; brachial cones present. *Lower Carboniferous (lower Serpukhovian):* Kazakhstan.——FIG. 387,*1a–c.* **B. rara,* Serpukhovian, Kazakhstan, Dzhezgazgan district; *a,b,* holotype, viewed ventrally, laterally, MGU 31/342, ×1 (Litvinovich, 1967); *c,* incomplete ventral valve internal mold, ×1 (Litvinovich & Vorontsova, 1991).

Datangia YANG DE-LI in YANG DE-LI & others, 1977, p. 369 [**D. luzhaiensis* NI SHI-ZHAO in YANG & others, 1977, p. 369; OD] [=*Datangia* YANG SHI-PU, 1978, p. 122 (type, *D. weiningensis,* obj.; *Moderatoproductus* LITVINOVICH & VORONTSOVA, 1983, p. 86 (type, *Gigantella moderata* SCHWETSOV, 1922, p. 10]. Poorly known; large; outline subcircular to oval; ribbing strong, even, no plications; spines at hinge, on ears, scattered ventrally; brachial cones absent. *Lower Carboniferous (Viséan):* China, northern Africa.——FIG. 387,*2a–c.* **D. luzhaiensis* (NI SHI-ZHAO), Lower Carboniferous, Datang Stage, Guangxi; ventral, posterior, lateral views of specimen, ×1 (Yang & others, 1977).

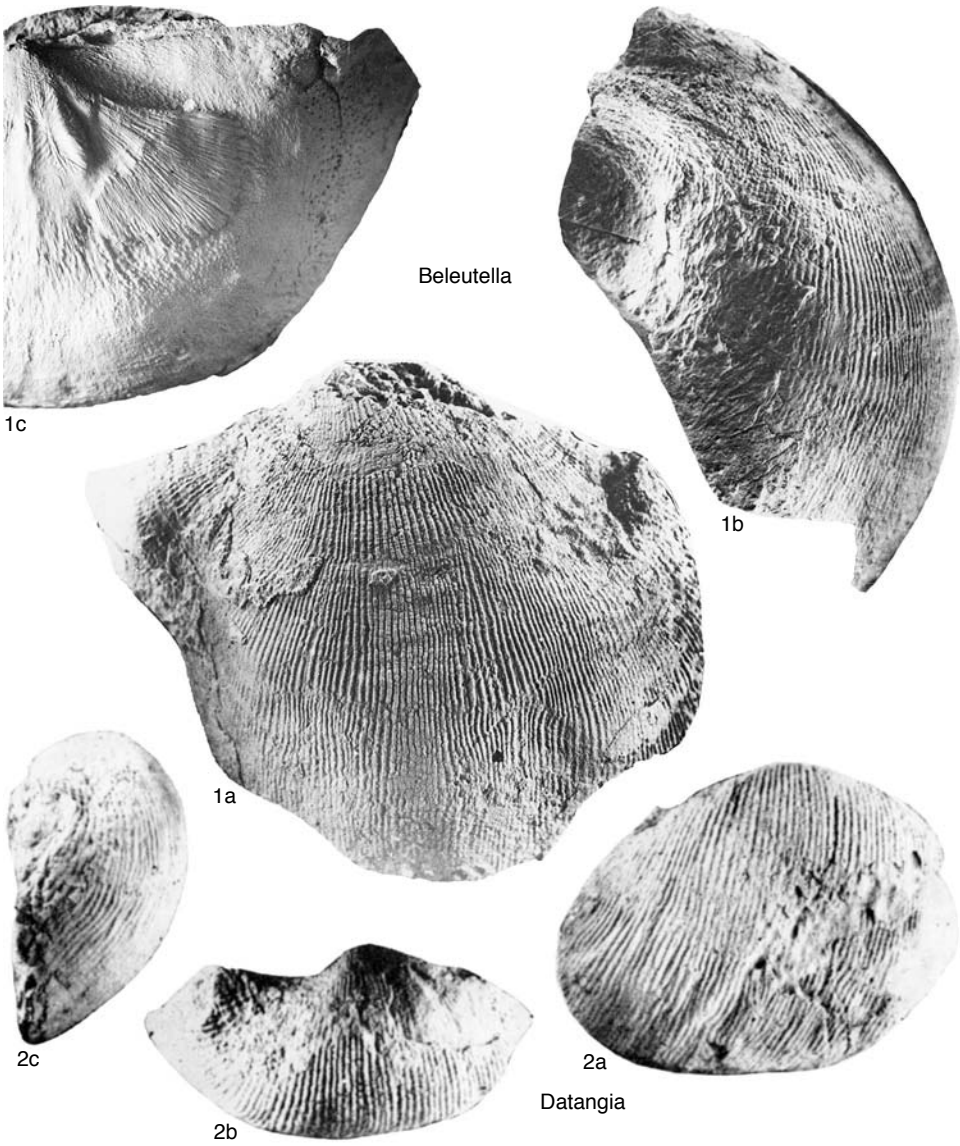

FIG. 387. Monticuliferidae (p. 551).

Globosoproductus LITVINOVICH & VORONTSOVA, 1983, p. 88 [**Gigantella magnifica* SCHIMANSKY, 1940, p. 106; OD]. Poorly known; large, somewhat ventrally inflated corpus; ribs fine posteriorly, where also reticulate, becoming coarser anteriorly; ventral spines sparse with thinner row near hinge, dorsal spines thin, rarely present; cardinal process narrow, bilobed; thin shelled, no brachial pits. *Lower Carboniferous (middle Viséan):* Russia.——FIG. 388,*1a–c.* **G. magnifica* (SCHIMANSKY), Lower Carboniferous, Tulsky, northern Urals; ventral valve viewed anteriorly, posteriorly, laterally, ×0.75 (Litvinovich & Vorontsova, 1991).

Kansuella CHAO, 1928, p. 67 [**Striatifera kansuensis* CHAO, 1927b, p. 108; OD] [=*Parakansuella* TAN ZHEN-XIU, 1987, p. 123 (type, *P. xinshaoensis;* OD)]. Transverse outline; weakly concavoconvex with weakly inflated ventral umbo and prominent ginglymus in both valves; rugae posteriorly, but weak anteromedianly; interiors as in *Gigantoproductus* but

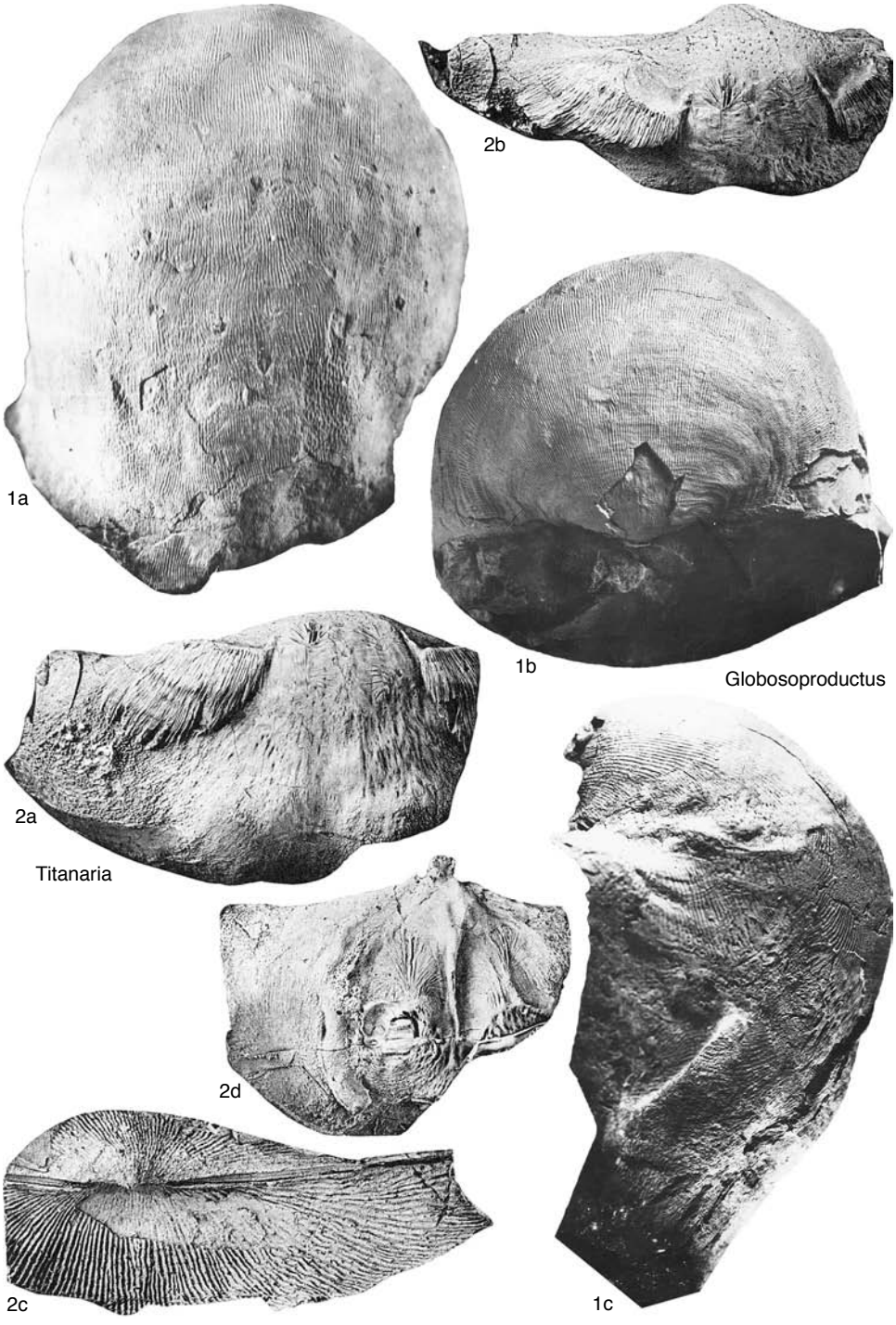

FIG. 388. Monticuliferidae (p. 552–555).

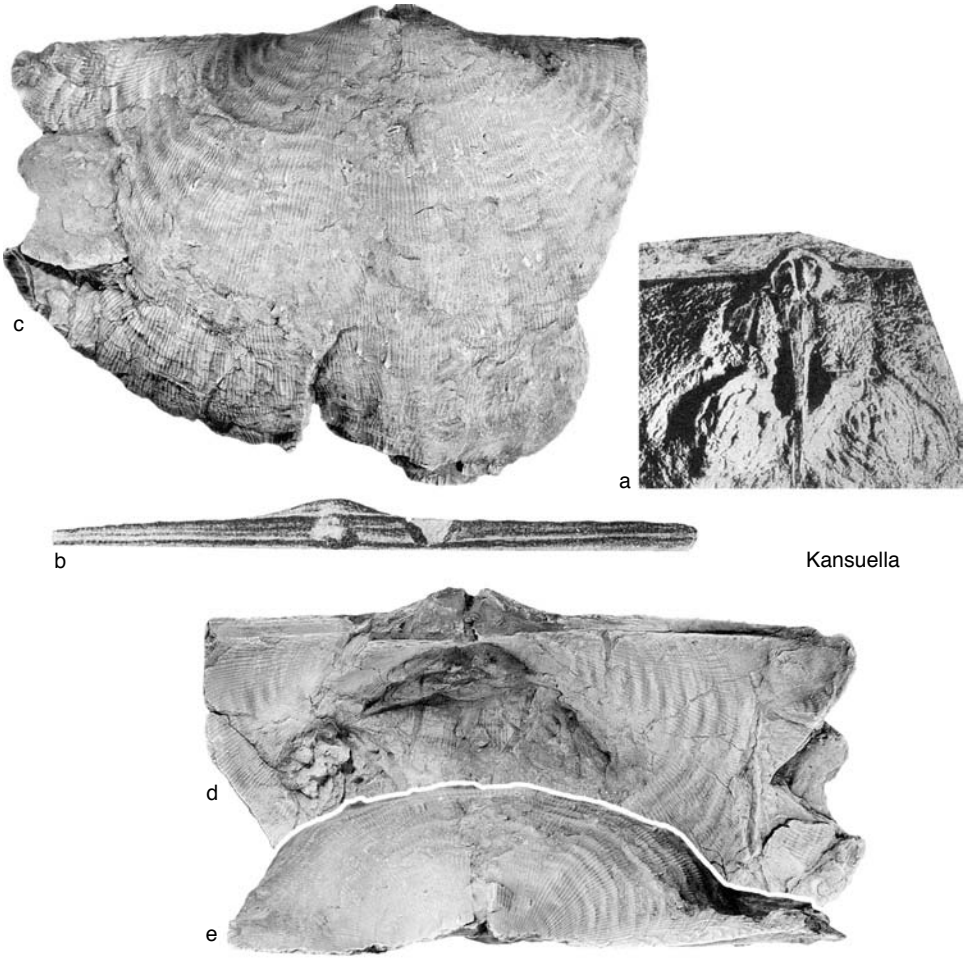

FIG. 389. Monticuliferidae (p. 552–554).

with bilobed cardinal process. [*Parakansuella* may differ in lacking rugae and more inflated ventral umbo.] *Lower Carboniferous (Viséan):* Eurasia.——FIG. 389*a,b.* **K. kansuensis,* Viséan, Kansu, China; *a,* incomplete dorsal valve internal mold, ×0.75; *b,* posterior view of shell with short ginglymus, ×0.75 (Muir-Wood & Cooper, 1960).——FIG. 389*c–e. Kansuella* sp., upper Viséan, Scotland; incomplete shell viewed ventrally, dorsally, posteriorly, ×0.75 (new).

Kueichowella YANG SHI-PU in FENG & JIANG, 1978, p. 267 [**K. kueichowensis;* OD] [=*Guizhouella* YANG SHI-PU, 1978, p. 124 (type, *G. guizhouensis* YANG SHI-PU, 1978, p. 125, obj.)]. Externally resembles *Kansuella,* but more strongly concavoconvex, no ginglymus; rugae cover valves fully; valves relatively thin shelled; cardinal process large, unifid. *Carboniferous (lower Serpukhovian):* China.——FIG. 390,*2a–c.* **K. kueichowensis,* lower Serpukhovian, Guizhou, originally figured as *G. guizhouensis; a,b,* holotype, viewed ventrally, posteriorly, MCMB F_{3}-2297, ×0.5; *c,* ventral valve exterior viewed posteroventrally, ×1 (Yang Shi-pu, 1978).

Serbarinia MOROZOV, 1985, p. 115 [**Productus kalugensis* SARYTCHEVA, 1928, p. 61; OD]. Resembles *Gigantoproductus,* but thin shelled; cardinal process trifid with strong median ridge; posterolateral internal surfaces strongly pustulose. *Lower Carboniferous (lower upper Viséan):* Russia.——FIG. 391*a–d.* **S. kalugensis* (SARYTCHEVA), lower Alexin, Moscow basin; *a,b,* replica of holotype, viewed ventrally, posteriorly, MGRI 30/27, ×0.5 (new); *c,* ventral valve interior, ×1; *d,* dorsal valve interior, ×1 (Sarytcheva, 1928).

Titanaria MUIR-WOOD & COOPER, 1960, p. 334 [**T. costellata;* OD]. Gigantic or large; transverse, resem-

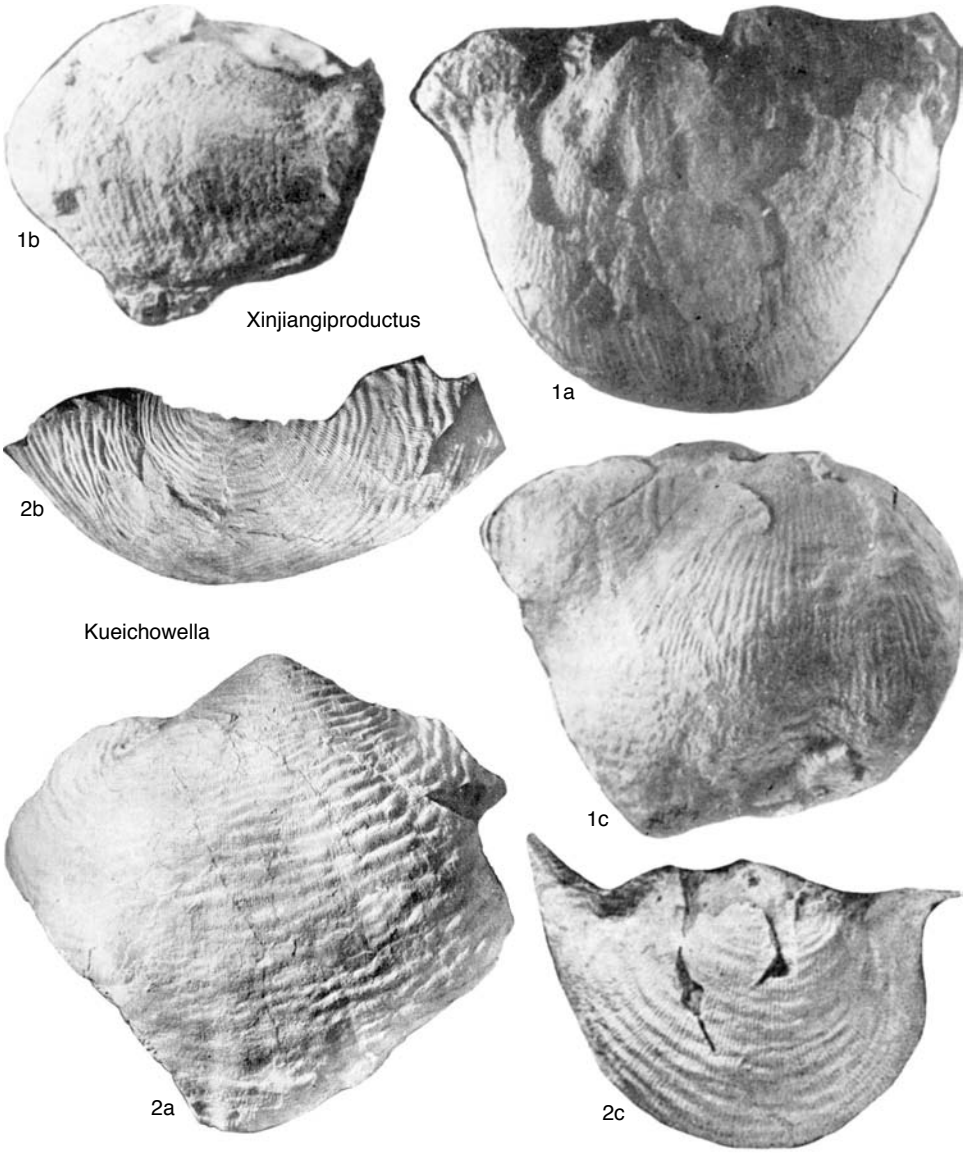

FIG. 390. Monticuliferidae (p. 554–556).

bling *Gigantoproductus,* but lacking rugae, anterior plications; ginglymus short; spines fine, widely distributed on both valves; ventral adductor scars between diductors; cardinal process trifid with strongly projecting median portion, brachial cones absent. *Lower Carboniferous (Viséan–lower Serpukhovian):* North America, North Africa.——FIG. 388,*2a–d. *T. costellata,* Chesterian, California; *a,b,* holotype, internal mold, viewed ventrally, posteriorly, USNM 8040a, ×0.8; *c,d,* replica of external mold, viewed posterodorsally and replica of incomplete dorsal valve interior, USNM 8040a, ×0.8 (Muir-Wood & Cooper, 1960).

Xinjiangiproductus YAO & FU, 1987, p. 96[101] [**X. yamansuensis;* OD]. Medium size; resembling *Datangia,* but with thick-shelled ventral valve and brachial cones; dorsal valve thin shelled. *Lower Carboniferous (Viséan–lower Serpukhovian):* China.——FIG. 390,*1a–c. *X. yamansuensis,* Lower Carboniferous, Xinjiang; *a,b,* holotype, partly exfoliated

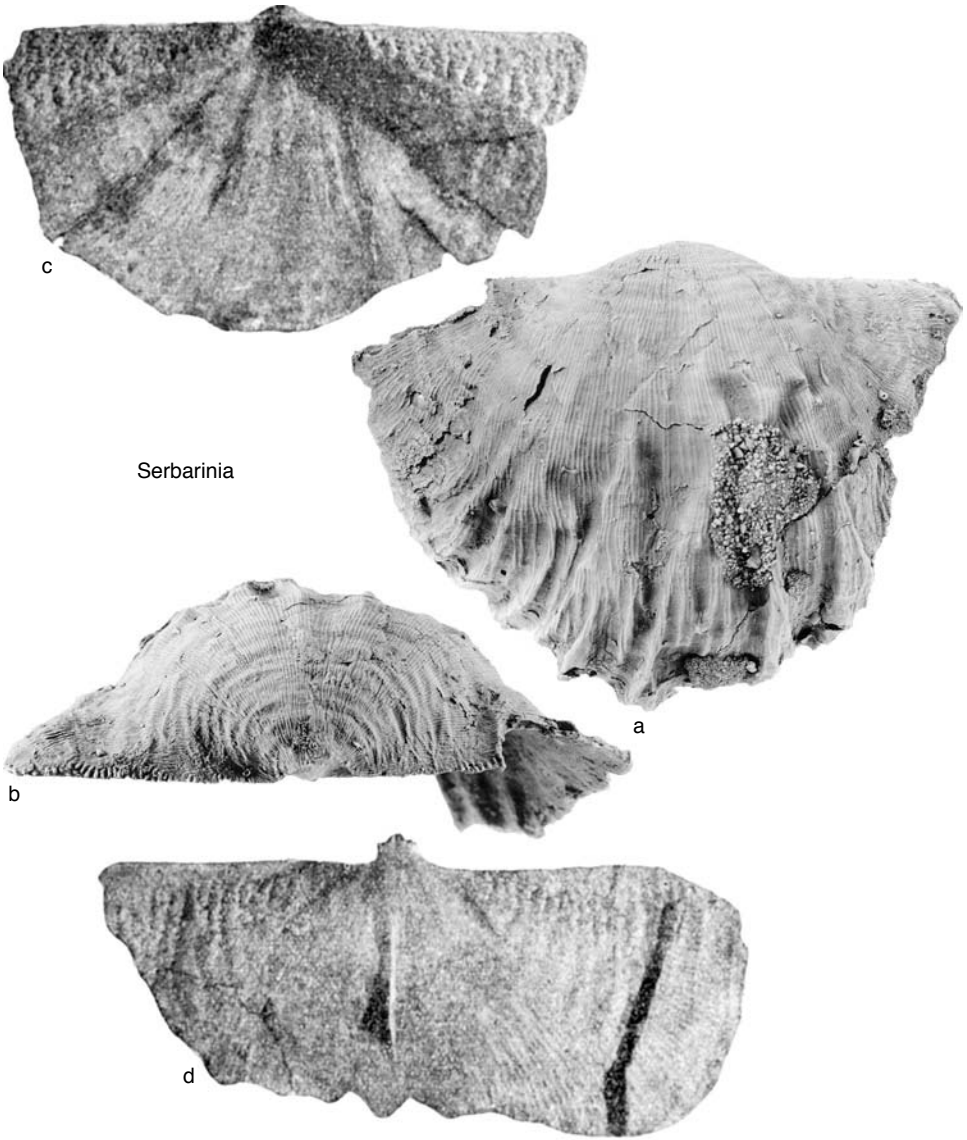

FIG. 391. Monticuliferidae (p. 554).

ventral valve viewed ventrally, laterally, ×1; *c,* exfoliated dorsal valve interior viewed anterolaterally, ×1 (Yao & Fu, 1987).

Tribe SEMIPLANINI Sarytcheva, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 930, Semiplanidae SARYTCHEVA in SARYTCHEVA, LICHAREW, & SOKOLSKAJA, 1960, p. 231]

Medium size to large, with very thin shell substance; ventral umbo strongly incurved; ribs of various widths; spines on both valves, some on ventral only; cardinal process bilobed or trifid, with median ridges poorly developed; no brachial cones. *Lower Carboniferous (middle Viséan–lower Serpukhovian).*

Semiplanus SARYTCHEVA in SARYTCHEVA & SOKOLSKAYA, 1952, p. 119 [**Productus semiplanus* SCHWETSOV,

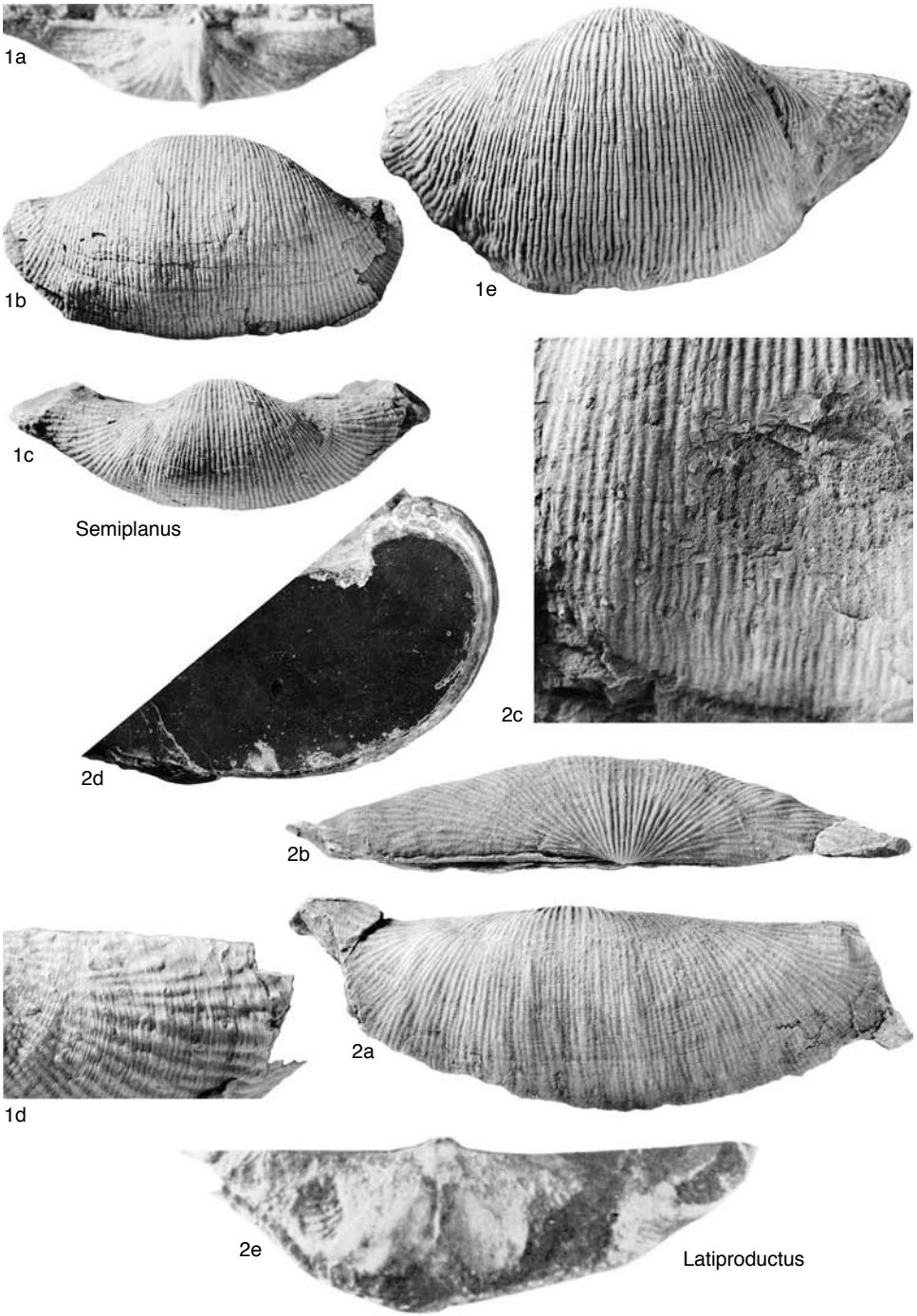

FIG. 392. Monticuliferidae (p. 556–559).

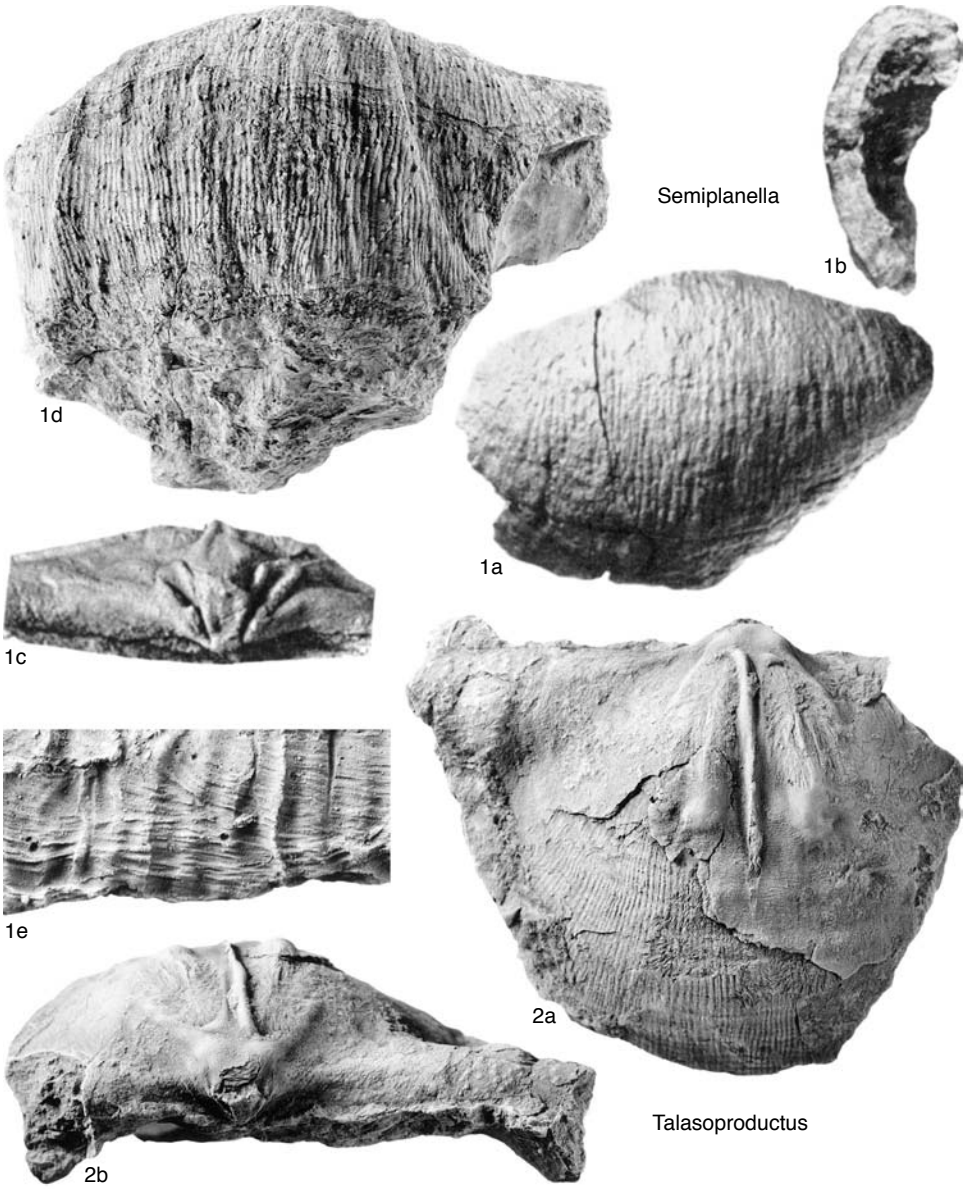

FIG. 393. Monticuliferidae (p. 559–560).

1922, p. 10; OD]. Medium to large; outline strongly transverse with poorly defined ears; ribbing distinct, entire; spines fine, numerous on both valves, less wide than ribs; cardinal process bilobed, becoming weakly trifid, supported by thick median septum; brachial ridges indistinct. *Lower Carboniferous (upper Viséan):* Eurasia.——FIG. 392,*1a–d. *S. semiplanus* (SCHWETSOV), Asbian, Isle of Anglesey, north Wales; *a,* dorsal valve interior viewed posteriorly, ×1.5 (Sarytcheva & Legrand-Blain, 1977); *b,c,* ventral valve exterior viewed anteroventrally, posteroventrally, ×1; *d,* detail of ear showing ornament, spine bases, ×3 (new).——FIG. 392,*1e. Semiplanus* sp., Derbyshire; ventral valve exterior showing spine bases, ×1 (new).

Latiproductus SARYTCHEVA & LEGRAND-BLAIN, 1977, p. 75 [**Productus latissimus* J. SOWERBY, 1822 in 1821–1822, pl. 330, fig. 2–3; OD]. Resembles *Semiplanus,* but lacking dorsal spines and with somewhat thicker ventral spines, ribbing; cardinal process trifid with short middle lobe. *Lower Carboniferous (Brigantian–lower Serpukhovian):* Eurasia, northern

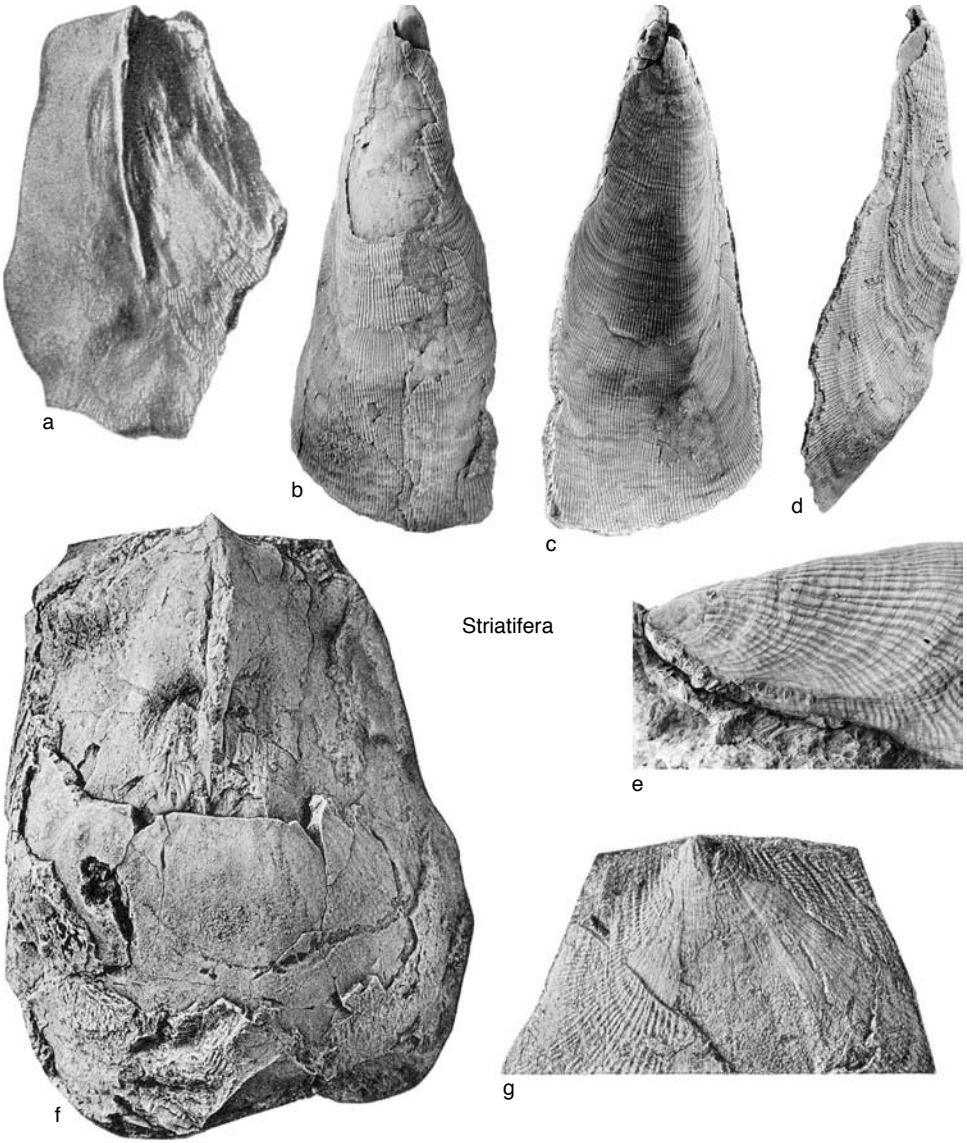

FIG. 394. Monticuliferidae (p. 560).

Africa.——FIG. 392,*2a–e. *L. latissimus* (J. SOWERBY), Brigantian, Isle of Anglesey; *a,b,* external mold of dorsal valve viewed ventrally, posteriorly, ×1; *c,* external ornament with spine bases, ×2; *d,* median longitudinal section showing ventral profile, ×1 (new); *e,* dorsal valve interior, ×1 (Sarytcheva & Legrand-Blain, 1977).

Semiplanella SARYTCHEVA & LEGRAND-BLAIN, 1977, p. 79 [**S. carinthica* SARYTCHEVA in SARYTCHEVA & LEGRAND-BLAIN, 1977, p. 81; OD]. Resembles *Semiplanus,* but with thick-shelled valves and sessile cardinal process with strong but short median lobe; cardinal ridges obscure; spines fine, more common ventrally; brachial ridges well defined. *Lower Carboniferous (upper Viséan):* western Europe, ?central Asia, ?northern Africa.——FIG. 393,*1a–e. *S. carinthica* (SARYTCHEVA), Brigantian, Carnic Alps, Austria; *a,b,* holotype, viewed ventrally, in section, PIN 3704/2, ×1; *c,* dorsal valve interior viewed posteriorly, ×3 (Sarytcheva & Legrand-Blain, 1977); *d,* anterior view of ventral valve exterior, ×1; *e,* segment of dorsal valve trail external mold with few spine bases, ×5 (new).

Talasoproductus LITVINOVICH & VORONTSOVA, 1983, p. 92 [**T. turlanensis;* OD]. Shell large but thin walled, lateral profile unusually gently convex;

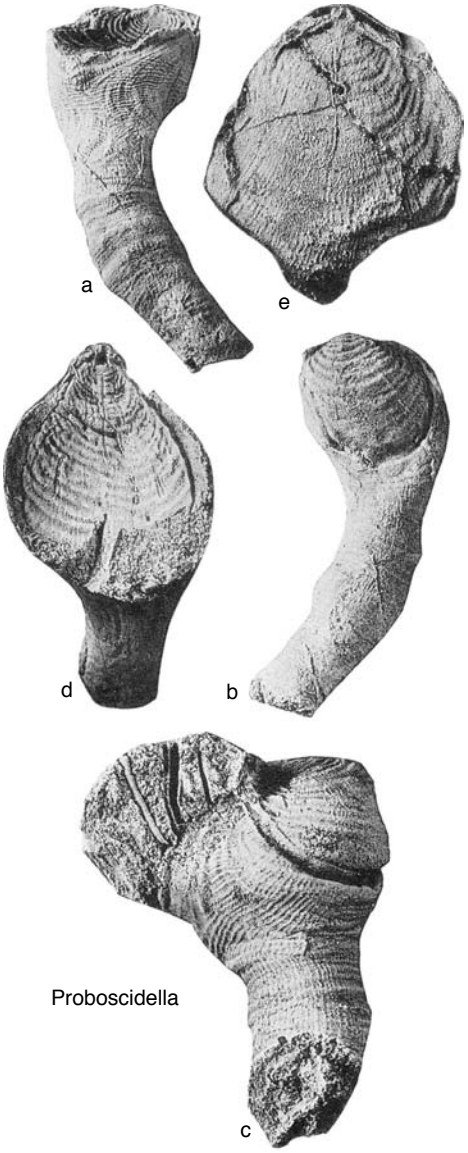

FIG. 395. Monticuliferidae (p. 560–562).

ribbing fine with narrow interspaces; spines confined to ventral hinge, ears; cardinal process with median, lateral portions equal; dorsal adductor scars bordered by ridges posterolaterally, lateral ridges short. *Lower Carboniferous (middle Viséan):* Kazakhstan.——FIG. 393,*2a,b.* **T. turlanensis,* middle Viséan, Kazakhstan; incomplete dorsal valve interior viewed ventrally, posteriorly, ×1 (new).

Subfamily STRIATIFERINAE Muir-Wood & Cooper, 1960

[Striatiferinae MUIR-WOOD & COOPER, 1960, p. 328]

Shell large to medium; outline elongate or with tubiform trail, hinge narrow; spines on ventral valve only. *Carboniferous (upper Viséan–Serpukhovian).*

Tribe STRIATIFERINI Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 930, *ex* Striatiferinae MUIR-WOOD & COOPER, 1960, p. 328]

Large, with very shallow corpus; trails simple; cardinal process of single ridge continuous with median septum. *Carboniferous (upper Viséan–Serpukhovian).*

Striatifera CHAO, 1927b, p. 94 [**Mytilus striatus* FISCHER DE WALDHEIM, 1837, p. 181; OD; *non Pileopsis striatus* PHILLIPS, 1836, p. 224]. Elongate, tapering posteriorly, flattened shell; spines ventral, clustered at ears and scattered on costellae; cardinal process commonly unifid, supported by long median septum. *Lower Carboniferous (upper Viséan–lower Serpukhovian):* Eurasia, northern Africa, North America.——FIG. 394*a–e.* **S. striata* (FISCHER DE WALDHEIM); *a,* dorsal valve interior, Asbian–Brigantian, Russia, ×1 (Muir-Wood & Cooper, 1960); *b–d,* corpus of specimen viewed ventrally, dorsally, laterally, upper Asbian, Belgium, ×0.75; *e,* lateral view of ventral umbo with spine bases marginally, British Isles, Yorkshire, ×3 (new).——FIG. 394*f,g. Striatifera* sp., Meramecian–Chesterian, Oregon; *f,* dorsal valve interior, ×1; *g,* partly exfoliated ventral valve viewed posteriorly, ×1 (Muir-Wood & Cooper, 1960).

Tribe PROBOSCIDELLINI Muir-Wood & Cooper, 1960

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 930, *ex* Proboscidellinae MUIR-WOOD & COOPER, 1960, p. 325]

Corpus cavity shallow; hinge narrower than maximum width; ventral trail long and forming tube, irregularly rugose; cardinal process bilobed, lateral, and submarginal ridges present. *Lower Carboniferous (upper Viséan).*

Proboscidella OEHLERT, 1887b, p. 1277 [**Productus proboscideus* DE VERNEUIL, 1840, p. 259; OD]. Corpus with weak rugae that may extend on ventral trail, forming long tube; spines strong at posterior margin, sparse or absent elsewhere. *Lower Carboniferous (upper Viséan):* Eurasia.——FIG. 395*a–e.* **P. proboscidea* (DE VERNEUIL), upper Viséan, Belgium;

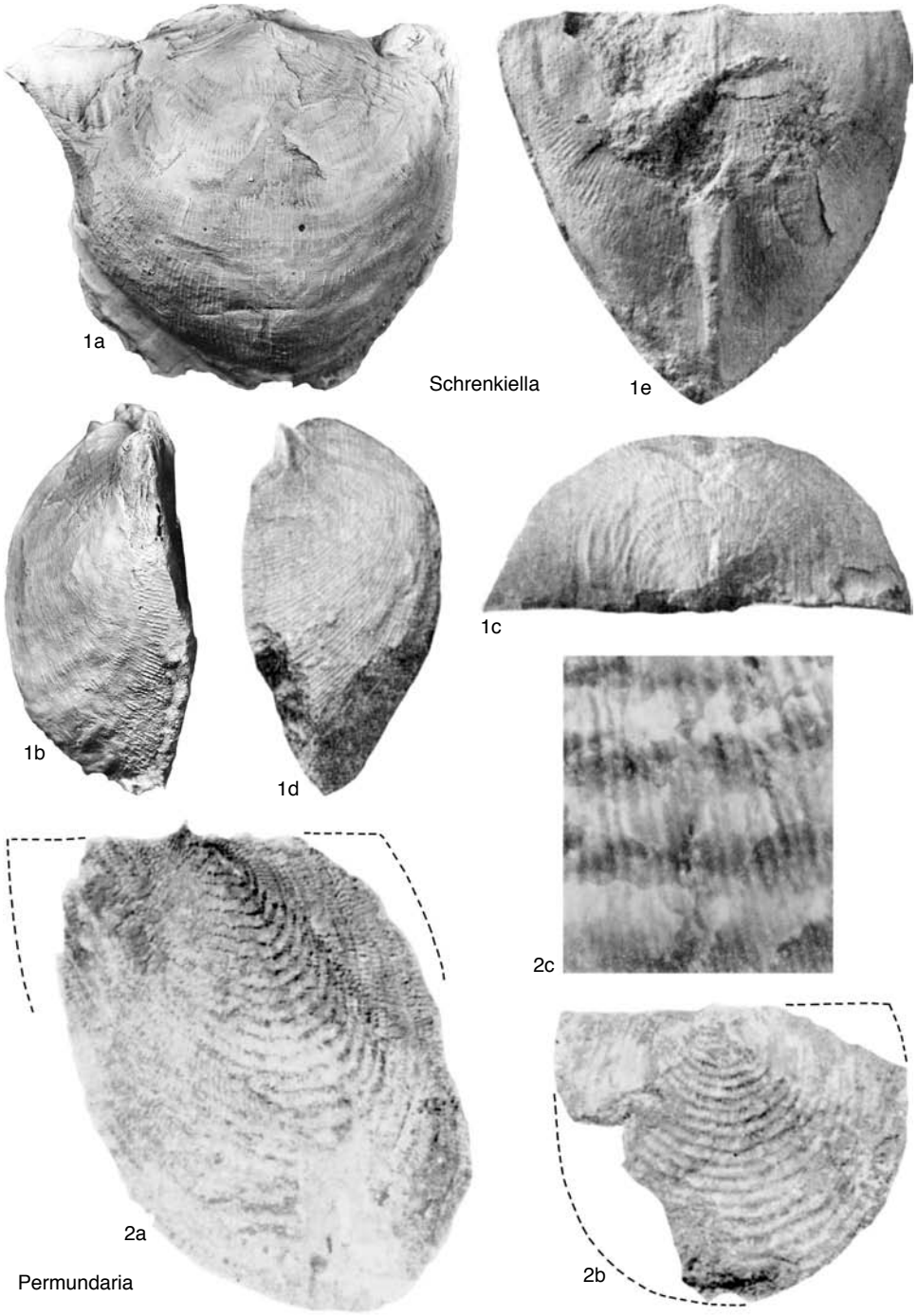

FIG. 396. Monticuliferidae (p. 562–563).

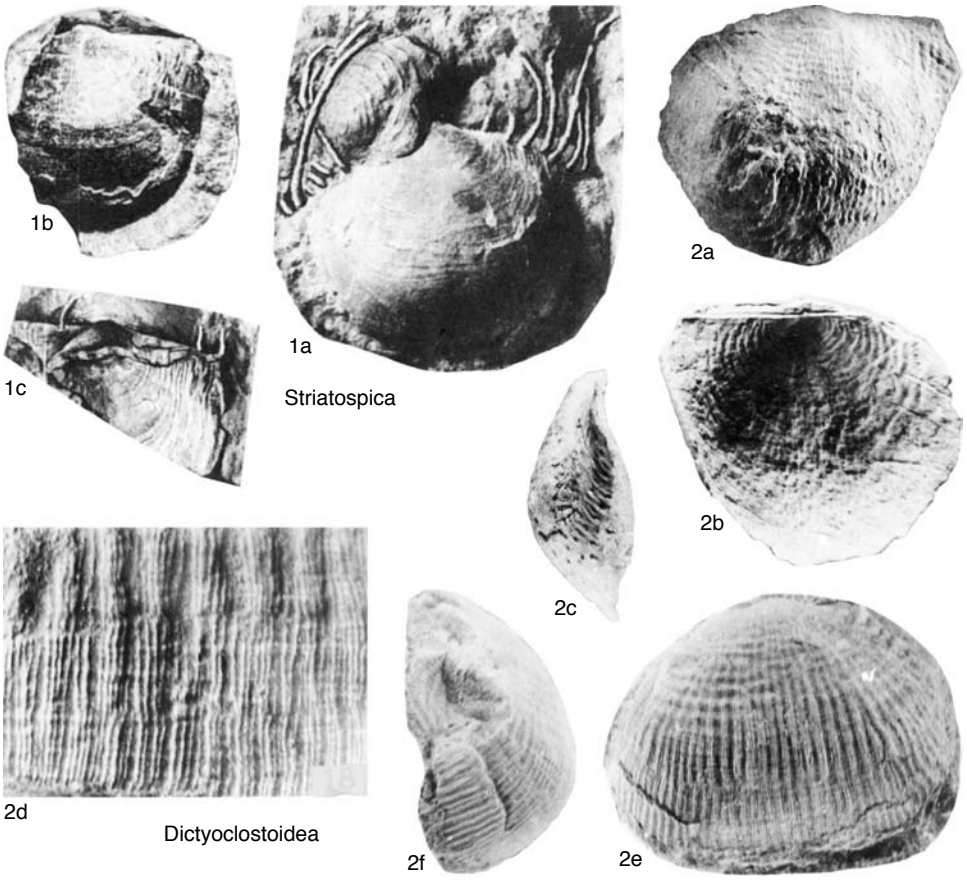

FIG. 397. Monticuliferidae (p. 562–563).

a,b, lateral, ventral views of almost complete specimen, ×3; *c,* oblique lateral view of shell with clasping spines, ×3; *d,* dorsal view of internal mold of shell, ×2; *e,* replica of dorsal valve interior, ×3 (Muir-Wood & Cooper, 1960).

Subfamily SCHRENKIELLINAE Lazarev, 1986

[Schrenkiellinae LAZAREV, 1986c, p. 30]

Medium size to large, with flattened ventral disk; spines in row near hinge margin only, ribs separated by wider interspaces, commonly with fine capillation; rugae may be present. *Lower Permian (Sakmarian)–Upper Permian (upper Capitanian).*

Schrenkiella BARCHATOVA, 1973, p. 97 [**Productus schrenki* STUCKENBERG, 1875, p. 88; OD] [=*?Achunoproductus* USTRITSKY, 1971, p. 21; *Indigia* BARCHATOVA, 1973, p. 100 (type, *I. ilibeica*)]. Medium to large, somewhat trapezoid to broadly trigonal with median ventral fold; visceral disks weakly curved; ribs fine, narrower than interspaces, tend to fluctuate in width; spines only recorded at ventral hinge. *Lower Permian (Sakmarian):* northern Russia, ?Australia.——FIG. 396,*1a,b.* **S. schrenki* (STUCKENBERG), Sakmarian, Timan; partly exfoliated ventral valve exterior viewed ventrally, laterally, ×1 (new).——FIG. 396,*1c,d. S. timanica* BARCHATOVA; specimen viewed posteriorly, laterally, ×1 (Barchatova, 1973).——FIG. 396,*1e. S. triangulata* (BARCHATOVA); exfoliated dorsal valve interior, ×1.5 (Barchatova, 1973).

Dictyoclostoidea JING & HU, 1978, p. 121 [**D. kiangsiensis* WANG & CHING in WANG, CHING, & FANG, 1966, p. 437; OD] [=*Dictyoclostoidea* WANG & CHING in WANG, CHING, & FANG, 1964, p. 264, *nom. imperf.; Dictyoclostoidea* WANG & CHING in WANG, CHING, & FANG, 1966, p. 437, *nom. imperf.;* ?=*Hypolinoproductus* LIANG in WANG & others, 1982, p. 212 (type, *H. changxingensis*)]. Closely resembles *Schrenkiella,* but possibly with more strongly developed rugae; capillae restricted to dor-

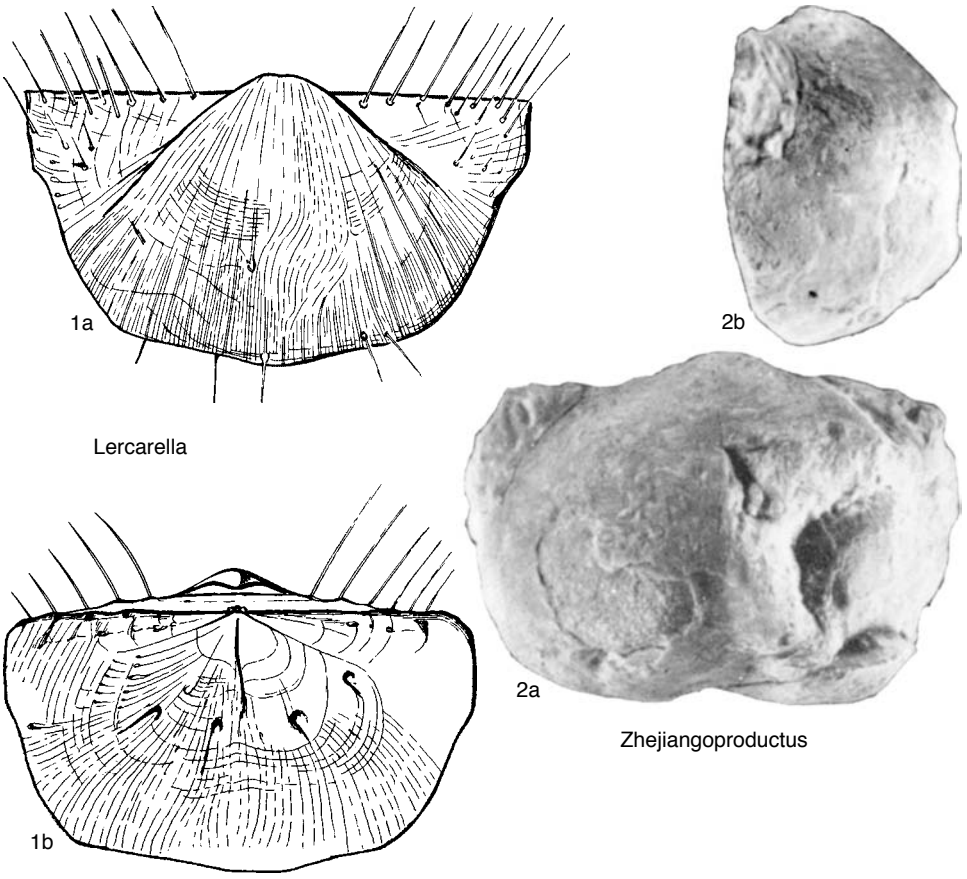

FIG. 398. Monticuliferidae (p. 563–564).

sal valve, rare spines on ventral valve; short ginglymus may be present. *upper Lower Permian (Artinskian)–lower Upper Permian (Kazanian):* eastcentral China.——FIG. 397,*2a–d. *D. kiangsiensis* WANG & CHING, Xiaojiangbian Limestone, Jiangxi; *a–c,* specimen viewed ventrally, dorsally, laterally, ×1.5; *d,* detail of dorsal valve ornament, ×5 (new).——FIG. 397,*2e,f. D. changxingensis* (LIANG), Chihsian Formation, Anhui; holotype, internal mold of ventral valve viewed ventrally, laterally, ZI 52803, ×1.6 (new).

Permundaria NAKAMURA, KATO, & CHOI, 1970, p. 295 [**P. asiatica;* OD]. Poorly understood genus; medium to large with very weakly concavoconvex profile; rugae, fine ribbing cover shell, but no spines reported. *Upper Permian:* Japan, Cambodia, southern China, Kashmir, ?Iran.——FIG. 396,*2a. *P. asiatica,* Upper Permian, Sisophon Limestone, Kitakami Mountains; holotype, ventral valve external mold, UHR 19015, ×1.4 (Nakamura, Kato, & Choi, 1970).——FIG. 396,*2b,c. P. sisophonensis* NAKAMURA, KATO, & CHOI; *b,* holotype, incomplete ventral valve exterior, UHR 19017, ×1.4; *c,* detail of ribbing, UHR 19017, ×10 (Nakamura, Kato, & Choi, 1970).

Striatospica WATERHOUSE, 1975, p. 11 [**Striatifera? kayseri* CHAO, 1927b, p. 115; OD]. Medium size with hinge forming widest part of shell; trail forming flange anteriorly, laterally; rugae fine on both disks; capillae on both valves, no costation; strong spine rows on ears, close to hinge only; interiors unknown. *Upper Permian (upper Capitanian):* China.——FIG. 397,*1a–c. *S. kayseri* (CHAO), Loping Formation, Jiangxi; *a,* holotype, ventral valve exterior, ?NIGP 1104, ×1; *b,* ventral valve exterior, ×1; *c,* external mold of part of dorsal valve, ventral umbo, ×1 (Chao, 1927b).

Subfamily UNCERTAIN

Lercarella MASCLE & TERMIER, 1970, p. 188 [**L. sicana;* OD]. Poorly known, large, transverse, widest at hinge with ginglymus or interarea; weakly concavoconvex with shallow corpus; spines near ventral hinge, on ears and rarely on venter; interiors poorly known, cardinal process possibly ventrally

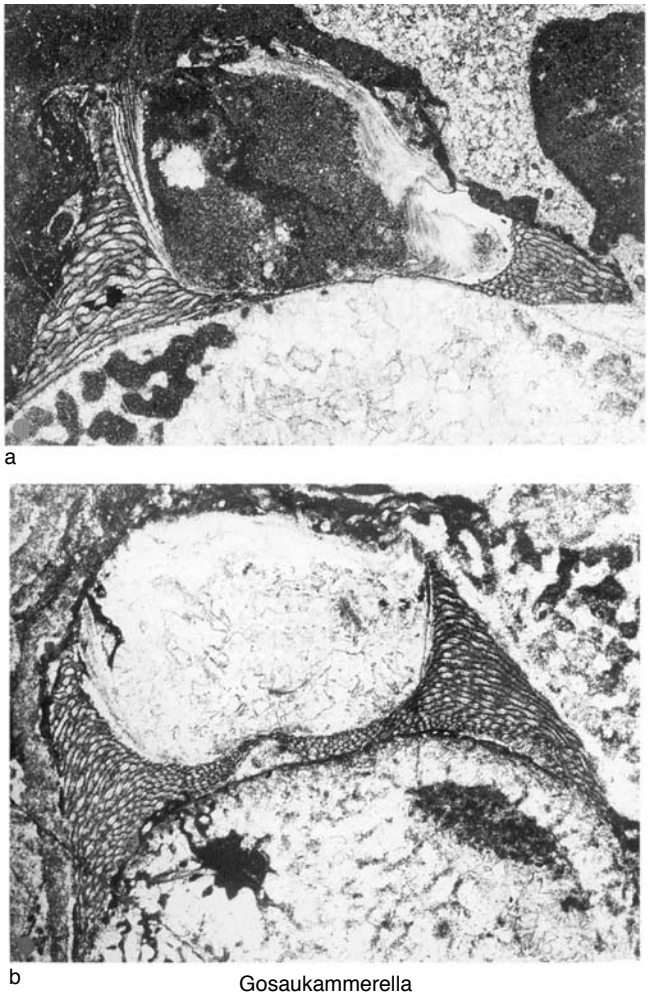

FIG. 399. Uncertain (p. 564–565).

directed, indicating relationship with the Strophalosiinae, otherwise possibly in Monticuliferidae. *Lower Permian:* Sicily.——FIG. 398,*1a,b. *L. sicana,* Lower Permian, Lercara Friddi; *a,* reconstruction of ventral valve, ×1; *b,* reconstruction of dorsal valve, ×1 (Mascle & Termier, 1970).

Zhejiangoproductus LIANG WEN-PING, 1990, p. 196[464] [**Z. zhejiangensis;* OD]. Poorly known, large with hinge equal to maximum width; ventral disk flattened, with convex trail; sulcus originating on ventral disk; spines at hinge line and ears, reportedly absent alsewhere; exteriors reportedly smooth other than rugae on ears. *Upper Permian (Kazanian):* China.——FIG. 398,*2a,b. *Z. zhejiangensis,* Kazanian, Lengwu Formation, Zhejiang; shell viewed ventrally and laterally, ×1.5 (Liang, 1990).

Superfamily UNCERTAIN

Gosaukammerella SENOWBARI-DARYAN & FLÜGEL, 1996, p. 92 [**G. eomesozoica;* OD; *=?Pycnoporidium eomesozicum* FLÜGEL, 1972, p. 968, possibly alga]. Minute, 2 to 3 mm wide, planoconvex corpus, thin valve walls, but ventrally with outgrowths of thick, symmetrical mass of tubules attaching to substrate; shell substance reportedly pseudopunctate, laminar; interiors unknown. [If a productide it is a long holdover that lived in a cryptic reef environment]. *?Upper Triassic (?Norian, ?Rhaetian):* alpine Mediter-

ranean region.——FIG. 399*a,b.* **G. eomesozoica,* Dachstein Reef Limestone, Norian, Austria; *a,* oblique longitudinal section of both valves, ×15; *b,* transverse section of ventral valve and tubular attachment structure, ×15 (Senowbari-Daryan & Flügel, 1996).

Suborder STROPHALOSIIDINA Schuchert, 1913

[*nom. transl.* BRUNTON, LAZAREV, & GRANT, 1995, p. 931, *ex* Strophalosiinae SCHUCHERT, 1913a, p. 391, *sensu* LAZAREV, 1989, *non* WATERHOUSE, 1978]

Productides with interareas in ventral valve only or both valves; commonly ventrally attached; profile includes conical shape; spines on ventral or both valves, rarely absent; toothed articulation retained or lost; cardinal process directed ventrally or posteroventrally, never dorsally.

This group of productides is tremendously varied in shape and habit, ranging from chonetid-like in profile to conical or flattened; attachment is by direct cementation of part of the ventral valve or by creeping, irregularly shaped spines. Carboniferous and Permian taxa tend to be adapted to live on hard substrates, commonly reef environments, and the various elaborations of trails appear to have been in response to these habitats. *Lower Devonian (Emsian)–Upper Permian (Changhsingian).*

Superfamily STROPHALOSIOIDEA Schuchert, 1913

[*nom. correct.* BRUNTON, LAZAREV, & GRANT, 1995, p. 931, *pro* Strophalosiacea MUIR-WOOD & COOPER, 1960, p. 71, *nom. transl. ex* Strophalosiinae SCHUCHERT, 1913a, p. 391]

Cicatrix commonly developed; corpus cavity shallow; teeth retained; brachial ridges commonly extending to disk margins. *Lower Devonian (Emsian)–Upper Permian (Changhsingian).*

Family STROPHALOSIIDAE Schuchert, 1913

[*nom. transl.* STEHLI, 1954, p. 328, *ex* Strophalosiinae SCHUCHERT, 1913a, p. 391]

Outline rounded; strong rhizoid spines over ventral or both valves, may be bidirectional; planoconvex profile, but corpus cavity rather shallow; trails short. *Lower Carboniferous (Hastarian)–Upper Permian (Changhsingian).*

Subfamily STROPHALOSIINAE Schuchert, 1913

[Strophalosiinae SCHUCHERT, 1913a, p. 391] [=Heteralosiinae MUIR-WOOD & COOPER, 1960, p. 80; Truncateninae LIAO, 1982, p. 539; Licharewiellinae ARCHBOLD, 1986, p. 98]

Spines on ventral valve only; plano- to weakly concavoconvex profile. *Lower Carboniferous (Hastarian)–Upper Permian (Changhsingian).*

Strophalosia W. KING, 1844, p. 313 [**S. gerardi* W. KING, 1846, p. 92; SD MUIR-WOOD & COOPER, 1960, p. 74] [=*Leptaenalosia* W. KING, 1850, p. 93, *nom. nud.*]. Medium, slightly transverse subrounded outline with ill-defined small ears; hinge less than maximum width; ventral interarea wide but short; weak concavoconvex profile; concentric ornament weak ventrally, lamellose dorsally; weak capillation may be present on dorsal valve; spines cover ventral valve, suberect, semirecumbent; lateral ridges ventrally, separating ears; medium septum connected to cardinal process, interrupted at adductor scars, reaching two-thirds disk length. *Lower Permian (Sakmarian)–Upper Permian (Kazanian):* Himalayas, Australia ?Arctic Russia, China, Salt Range. ——FIG. 400,*1a–c.* **S. gerardi* W. KING, Ladakh, Himalayas; *a,b,* lectotype, viewed ventrally, dorsally, FC D 267, ×1.5; *c,* incomplete dorsal valve interior, ×1.5 (Brunton, 1966).——FIG. 400,*1d–f.* *S. irwinensis* COLEMAN, Callytharra Formation, Carnarvon basin, Australia; *d,* ventral valve exterior, ×1.2; *e,* ventral valve internal mold, ×1.6; *f,* dorsal valve interior, ×2 (Archbold, 1986).

Coronalosia WATERHOUSE & GUPTA, 1978, p. 415 [*C. blijniensis;* OD]. Similar to *Strophalosia,* but with fine ventral spines, other than at hinge line; relatively smooth dorsal valve exterior. Published figures inadequate for illustration. *Lower Permian (?Sakmarian):* India.

Craspedalosia MUIR-WOOD & COOPER, 1960, p. 82 [**Orthothrix lamellosa* GEINITZ, 1848, p. 86; OD]. Resembles *Dasyalosia* ventrally, but with dorsal valve strongly lamellose, lacking spines. *upper Lower Permian (Roadian):* Europe.——FIG. 401,*1a–d.* **C. lamellosa* (GEINITZ), lower Zechstein, Gera, Germany; *a–c,* shell viewed ventrally, dorsally, laterally, ×2; *d,* dorsal valve interior, ×2 (Muir-Wood & Cooper, 1960).

Etherilosia ARCHBOLD, 1993, p. 11 [**Strophalosia etheridgei* PRENDERGAST, 1943, p. 43; OD]. Small, subcircular with hinge less than maximum width; resembling *Heteralosia,* but differing in its relatively larger cicatrix, distinct rhizoid spines, in having only ventral uniform, suberect spines. *Lower Permian*