

A NEW SPECIES OF *SABATIA* (GENTIANACEAE) FROM SALINE COUNTY, ARKANSAS

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ABSTRACT

Sabatia arkansana, a new species from shale and igneous glades in central Arkansas, is described. It differs from *S. campestris* in its narrower leaves and narrower, more deeply colored corolla lobes rounded at the apex.

RESUMEN

Se describe ***Sabatia arkansana***, especie nueva de claros de esquistos y de rocas ígneas en Arkansas central. Se diferencia de *S. campestris* por las hojas más angostas y por los lóbulos de la corola más angostos, coloreados más intensamente, y redondeados en el ápice.

HISTORY OF THE DISCOVERY

In June 2001, while collecting plants for the Flora of Arkansas Project and for his Master's thesis, the junior author was shown a small shale glade (Womble Formation) northwest of Owensville, Saline County, Arkansas, by nature photographer and amateur botanist John Pelton. Pelton, a long-time student of the flora of Arkansas and of Saline County in particular, was especially interested in showing Witsell plants of a *Sabatia* that he was unable to identify to species. Witsell collected specimens of this plant, as well as specimens of *Sabatia campestris* Nutt., which occurred in the same area.

Studies using all relevant botanical references available at the Arkansas Natural Heritage Commission and the University of Arkansas at Fayetteville Herbarium (UARK) supported the idea that this species was significantly different from any described in the literature. In any of the regionally appropriate keys, specimens of this plant keyed out to *S. campestris*. However, seeing *S. campestris* and this new species occurring at the same site made the differences between the two obvious (Fig. 3).

Conversations with the landowner at this site revealed the existence of another, larger glade opening 0.2 mile (0.3 km) northwest of the known glade. This glade was impressive in its botanical diversity and in that two intermittent spring-fed streams flow into the glade and join before flowing out of the glade downslope. More plants of this new *Sabatia* were found in this opening,

which should be considered part of the same complex rather than a completely separate site.

In June 2002, while conducting surveys for the rare small-headed pipewort (*Eriocaulon kornickianum*) on igneous glades near Bauxite, Saline County, Arkansas, Witsell and Pelton located several more populations of this *Sabatia*.

Witsell compared the Saline County specimens with *Sabatia* specimens from a broader region at the herbarium of the Missouri Botanical Garden (MO) in July 2002. When no matches were found at MO, the Saline County specimens were sent to the senior author for confirmation that this was indeed a species new to science.

DESCRIPTION OF THE SPECIES

Sabatia arkansana J.S. Pringle & C.T. Witsell, sp. nov. (**Figs. 1–5**). TYPE: ARKANSAS: Saline Co.: Alcoa Lake Glades Natural Area, 3.5 mi (5.6 km) SE of Bauxite, NE 1/4 of SW 1/4 of Section 26, T2S R14W, northernmost glade opening on W shore of lake, 18 Jun 2002, Witsell 02-0832 (HOLOTYPE: UARK; ISOTYPE: MO).

Sabatia campestris affinis sed foliis linearibus vel anguste lanceolatis et corollis atroroseis lobis anguste spathulatis apicem versus rotundatis differens.

Annuals; roots fibrous. Plants 7–25 cm tall, single-stemmed at base. Stems \pm terete but narrowly 4-winged; proximal diameter 0.4–1.3 mm, wings ca. 0.1–0.2 mm high; branching generally alternate (rarely opposite proximally), mostly at 30–50°, lowest branching ca. mid-height. Proximal internodes 0.8–2 \times as long as subtending leaves, distal internodes 0.6–1 \times as long. Leaves all cauline, bright green, membranous, spreading, linear to lanceolate; most leaves 7–30 \times 1–4.5(–6) mm; bases narrowed, not clasping, apices obtuse (proximal leaves) to acute or acuminate (mid-stem and distal leaves); leaves smaller near base of stem, lowermost leaves minute. Inflorescence a \pm corymboid, monochasial cyme; flowers 1–12(–18) per plant. Pedicels (2–)10–40 mm. Perianth and androecium pentamerous. Calyx (0.7–)1.0–1.4 \times as long as corolla; tube turbinate, green along commissural veins, otherwise whitish and nearly hyaline, 2.8–5.5 mm, 0.7–0.9 \times as long as corolla tube; ridges present along commissural veins of tube, triangular in cross-section, rounded or distally acute along apex but not winged, widening from 0.2–0.5 mm at base to 0.5–0.8 mm at summit of tube, where there is sometimes a minute protuberance, dividing into lower ridges along submarginal veins of lobes; lobes green, spreading at 60–90°, nearly filiform to linear, 9–13 \times 0.6–1.2 mm, apices acute. Corolla deep but bright magenta-pink, with an oblong-triangular, sometimes apically notched yellow zone extending from tube into each lobe along midrib, alternating with shorter, yellowish-white zones flanking sinuses; tube 3–7 mm; lobes narrowly spatulate-obovate, 8–18 \times 3–6 mm, apices rounded. Filaments (3–)4–5.5 mm, ca. 1.5 \times as long as uncoiled anthers; anthers yellow, 2.3–3.5 mm long before coiling. Pollen grains subprolate, 33–38 μ m long, 27–34 μ m in diameter. Uncleft portion of style 2–3.5 mm, style



Fig. 1. *Sabatia arkansana*, holotype.

branches plus stigmas when uncoiled (3–)4.5–6 mm, 1.7–2.5 \times as long as unclift portion.

PARATYPES: **ARKANSAS: Saline Co.:** Bauxite, sandy outwash on rock outcrop, 6 Jun 1950, *Moore 50-0161* (UARK); locality and date uncertain (see note below), *Moore 50-0168* (UARK); Womble Shale glade on W side of Burk Rd. NW of Owensville, 21 Jun 2001, *Witsell 01-0474*; Alcoa Clear Lake Glade, 2.5 mi (4.0 km) ESE of Bauxite, N 1/2 of NW 1/4 of NW 1/4 of Section 23, T2S R14W, 18 Jun 2002, *Witsell 02-0829*; Womble Shale glade E of Burk Road and W of the Middle Fork of the Saline River, NW of Owensville, NE 1/4 of SE 1/4 of Section 17, T1S R17W, 18 Jun 2002, *Witsell 02-0825*; International

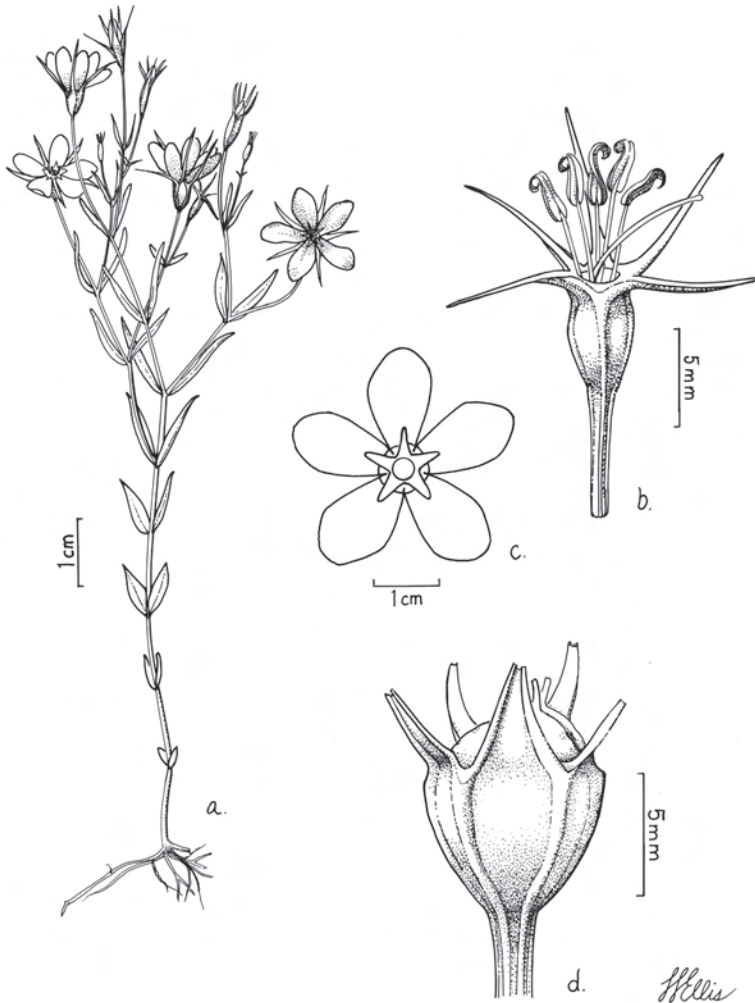


FIG. 2. *Sabatia arkansana*. **A.** Plant (*Witsell 02-0829*, UARK). **B.** Flower, lateral view with petals removed, anthers newly dehiscent and the stigma not yet receptive (*Witsell 02-0832*, UARK). **C.** Flower, adaxial view with stamens and sepals removed (*Witsell 02-0832*, UARK). **D.** Capsule, largely enclosed in persistent calyx (*Witsell 02-1125*, UARK).

Paper Pipewort Glades Preserve [now Dunnahoo Preserve, The Nature Conservancy], 3.5 mi (5.6 km) SE of Bauxite, NE 1/2 of NE 1/4 of Section 34, T2S R14W, 19 Jun 2002, *Witsell 02-0838*; Dry Lost Creek Glades, 1.75 mi (2.8 km) SE of Bauxite, E 1/2 of SE 1/4 of Section 21, T2S R14W, 19 Jun 2002, *Witsell 02-0840*; Womble Shale glades E of Burk Road and W of the Middle Fork of the Saline River, NW of Owensville, NE 1/4 of SE 1/4 of Section 17, T1S R17W, 10 Aug 2002, *Witsell 02-1125*. Unless otherwise indicated, specimens are in the herbarium of the Arkansas Natural Heritage Commission.

The two specimens collected by D.M. Moore in 1950 were originally identified as *Sabatia campestris*. *Moore 50-0161* was labeled as being collected at Bauxite 6 June. *Moore 50-0168*, although bearing a higher number, was labeled as being collected 15 miles south of Little Rock, near Ferguson Lake, the previous day. Ferguson Lake is in extreme southeastern Saline County, on unconsolidated Tertiary and Quaternary sediments (Haley et al. 1976). No rock outcrops or glades—that is, no suitable habitats for *S. arkansana*—are known from the area. It is unlikely that *S. arkansana* actually occurred at this site, and it may be that specimens from the two sites were mixed up.

The genus *Sabatia* Adans. and its sections and subsections have been described by Wilbur (1955). *Sabatia arkansana* is unequivocally a species of sect. *Campestris* J.D. Perry. This section, which is well defined morphologically and isolated genetically, is most readily recognizable by its calyx morphology (Wilbur 1955; Perry 1971). In all species in the section, prominent ridges extend along the commissural (fused lateral) veins from the base of the calyx to the sinuses between the lobes. At the sinuses they divide and extend along the submarginal veins of the adjacent lobes. The commissural and submarginal veins, therefore, are more prominent than the midveins, which are not ridged. In the other sections the calyx tubes either lack ridges along the veins or have low-ridged commissural veins that are no more prominent than the midveins. Plants in sect. *Campestris* are annuals, and the branching is entirely or predominantly alternate. The flowers are pedicellate and are pentamerous except for the carpels. Except in *S. arenicola*, the eye of the corolla is of the shape and pattern described above for *S. arkansana*, as contrasted with the more widely triangular yellow zones of most species with pink corollas in the other sections. The stamens are inserted immediately below the sinuses of the corolla. The combinations of style branches plus stigmas are linear. The morphology of *S. arkansana* is consistent with that of the section in all of these respects.

Sabatia arkansana exhibits the syndrome of floral morphology associated with predominantly allogamous pollination in *Sabatia* (Hill 1891; Perry 1971). The corollas are showy and brightly colored, with sharply contrasting eyes. The flowers are protandrous. Initially the styles and stigmas are bent nearly horizontally to one side, and the style branches are helically coiled around each other, so that the stigmatic surfaces are not exposed. At this stage the stamens are nearly erect. The anthers, when mature, coil circinately at the tip, with the rest of the anther still being straight and nearly erect when the pollen sacs dehisce. Subsequently the stamens diverge and the whole anther curves into a bassclef shape. The stigmas then become receptive. The uncleft portion of the style becomes erect, and the branches diverge and uncoil more or less completely.

Etymology and common name.—We name this new species *Sabatia arkansana* for the state to which it is apparently endemic. We propose the common name



FIG. 3. *Sabatia arkansana* (right), with *Sabatia campestris* (left) at the Womble Shale glade site. Photo by John Pelton.

“Pelton’s rose-gentian” in honor of John Pelton, who first noticed that this species was distinct from *S. campestris*, but was too humble to allow a scientific name to be given in his honor. He has done much to further our knowledge and appreciation of the flora of Arkansas through his insight, his photography, and his encouragement and tutelage of younger students of the flora.

COMPARISON WITH RELATED SPECIES

Only three species, or in some treatments only two, have generally been recognized in sect. *Campestris* (Wilbur 1955; Perry 1971; Bell & Lester 1980). The leaves of *S. arkansana* are narrower than those of any other species in the section. The mid-stem leaves of the largest plants of *S. arkansana* are linear to narrowly lanceolate, 4–8× times as long as wide, with three primary veins. Except for one pair of leaves on one plant that were 6 mm wide, the maximum width of any leaf seen was 4.5 mm. All leaves of the smaller plants are linear, 1–2 mm wide, with one primary vein. Also uniquely in the section, the corolla lobes of *S. arkansana* are narrowly spatulate-obovate, generally more than 1.8× and often more than 2.2× as long as wide. They are widest at ca. 0.8× their length. The apex is rounded.

Sabatia campestris Nutt., the most widespread species in sect. *Campestris*, is the most similar to *S. arkansana*. Both *S. arkansana* and *S. campestris* (Witsell 01-0473) were found at the locality where Witsell 01-0474 was collected. At this



FIG. 4. *Sabatia arkansana*, habit. Photo by John Pelton.



FIG. 5. *Sabatia arkansana*, detail of inflorescence. Photo by John Pelton.

site as elsewhere *S. arkansana* appears distinctly different in the field, and does not intergrade with *S. campestris*. Plants of *S. campestris* are larger than those of *S. arkansana* in nearby sites. Its leaves are ovate to lance-elliptic, 8–40 mm long \times 5–20 mm wide, with clasping, rounded to subcordate bases. The ridges on its calyx tube have a distinct wing or keel along the apex, ca. 1.0 mm high, which projects slightly above the sinus. Its corollas are a paler, less purplish shade of pink. Its corolla lobes are obovate, less than 1.8 \times as long as wide, and are widest at ca. 0.6 \times their length. The apex is usually abruptly acute, occasionally obtuse.

The pollen grains of *Sabatia* are tricolporate, with a finely reticulate exine. Perry (1971) concluded that pollen size was not useful as an indicator of ploidy or as a species characteristic, and that neither shape nor exine sculpturing differed significantly among the species. The pollen of *S. arkansana*, however, is subprolate, and grains in equatorial view are as numerous as those in polar view or more so on a microscope slide. That of *S. campestris*, as seen in the present study, is more nearly spherical, 26–30 μ m in diameter, i.e., slightly smaller than that of *S. arkansana*, and, as noted by Perry (1971), nearly always appears in polar view when placed on a slide.

At the Womble Formation locality near Owensville, *S. arkansana* is confined to open, flat, seasonally wet, narrow floodplains and seepage areas, whereas *S. campestris* grows in better-drained, steeper, drier microhabitats. Each of the two species occupies a distinct zone within the glades. Occasional plants of *S. campestris* occur within the microhabitat occupied by *S. arkansana* (Fig. 3) and, as noted above, no intergradation has been observed. *Sabatia campestris* is apparently absent from all of the glades on the nepheline syenite batholith near Bauxite. The two species also differ distinctly in phenology. Based on observations from 2001 through 2004, *S. arkansana* typically begins flowering 7 to 10 days before *S. campestris*, and *S. campestris* continues flowering at least 7 days after *S. arkansana*.

Sabatia formosa Buckley is known from Louisiana, Oklahoma, and Texas. It is recognized here following Bell and Lester (1978, 1980), but has often been included in *S. campestris* (Wilbur 1955). *Sabatia arkansana* is more similar to *S. formosa* than to *S. campestris* in its corolla color and markings but not in other respects. *Sabatia formosa* has closely spaced basal and near-basal leaves, which are larger than the mid-stem leaves and are generally present at flowering time, whereas in *S. arkansana* there is no evidence from crowded leaf-scars that a basal rosette is present at any stage. The proximal and mid-stem leaves of *S. formosa* are lanceolate to ovate, 8–25 \times 3–13 mm. Its calyces are usually shorter than the corollas. Its corolla lobes are elliptic-rhombic, less than 1.8 \times as long as wide, and are widest near the middle, tapering to an obtuse to acute apex.

Sabatia arenicola Greenm. (including *S. carnosa* Small) is a seabeach species, native along the Gulf Coast from Louisiana to Tamaulipas. Unlike *S.*

arkansana it frequently branches from near the base, and its relatively copious and dense branching is proximally more often opposite than that of the other species in section *Campestris*. Its leaves are succulent when fresh and blacken upon drying. They are elliptic to ovate or obovate, $6\text{--}27 \times 2\text{--}13$ mm. Its calyx lobes are oblong-lanceolate to narrowly ovate-triangular. It differs further in exhibiting the floral morphology associated with autogamy in *Sabatia*. It has relatively small corollas, which are white or light pink with the eyes whitish and less sharply defined than those of the allogamous species. The styles are nearly erect when the flowers open, and the stigmas are receptive concurrently with rather than after the dehiscence of the anthers.

Only two other validly published names have been associated with sect. *Campestris*, and it is evident that neither was based on specimens of *S. arkansana*. *Sabatia nervosa* Raf. was included in *S. campestris* by Wilbur (1955). Its leaves were described as ovate-lanceolate and its corolla lobes as broadly obovate. The identity of *S. concinna* Alph. Wood, which presumably was based on specimens from Indiana, is uncertain. It was described as having opposite branching, which would be inconsistent with its inclusion in sect. *Campestris*, and calyces only half as long as the corollas.

Small plants of *S. campanulata* (L.) Torr., in sect. *Sabatia* subsect. *Campanulatae* S.F.Blake, are somewhat similar to *S. arkansana* in aspect. *Sabatia campanulata* is an extremely rare (S1) species in Arkansas. It has narrow leaves and calyx lobes, but the plants are perennial, usually with clustered stems, and the pedicels are mostly 40–70 mm. The calyx tube of *S. campanulata* is obconic, only 1–3 mm long and less than $0.5\times$ as long as the corolla tube. Ridges along the commissural veins are absent or low and no more prominent than those along the midveins.

Sabatia arkansana cannot plausibly be interpreted as a recurrently produced interspecific hybrid. In most populations it is the only *Sabatia* species present. Other than *S. campestris*, the only *Sabatia* that has been found in the vicinity of *S. arkansana* is *S. angularis* (L.) Pursh, in sect. *Sabatia* subsect. *Angulares* S.F.Blake. *Sabatia angularis* does not intergrade with *S. arkansana*, and its morphology, which includes opposite branching, stem wings 0.2–0.3 mm high, and lanceolate to ovate leaves 5–30(–40) mm wide, does not suggest that it might be a parent of *S. arkansana*. The only other *Sabatia* species known from Arkansas are *S. brachiata* Ell., in sect. *Sabatia* subsect. *Angulares*, and *S. gentianoides* Ell., in sect. *Pseudochironia* Griseb. The first is uncommon in Arkansas, and the latter is extremely rare (S1) in the state. No intersectional hybrids in *Sabatia* are known in nature (Wilbur 1955; Perry 1971). All of Perry's (1967) attempts to make intersectional crosses involving species in sect. *Campestris*, including *S. campestris* \times both *S. angularis* and *S. campanulata*, were unsuccessful.

KEY TO THE SPECIES OF *SABATIA* SECT. *CAMPESTRIA*

1. Leaves succulent when fresh, blackening in drying, elliptic to ovate or obovate; corolla lobes 4–10(–13) mm _____ **Sabatia arenicola**
1. Leaves not succulent nor blackening, linear to ovate; corolla lobes 8–25 mm.
 2. Basal leaves usually present at flowering time; calyces usually shorter than corollas; corolla lobes elliptic-rhombic, widest near mid-length _____ **Sabatia formosa**
 2. Basal leaves absent at flowering time; calyces usually as long as or longer than corollas; corolla lobes spatulate to obovate, widest distally.
 3. Leaves all lanceolate to linear, generally less than 5 (rarely to 6) mm wide; corolla lobes deep magenta-pink, more than 1.8× as long as wide, widest at ca. 0.8× or more of their length, rounded at apex _____ **Sabatia arkansana**
 3. Leaves except in distal portions of inflorescence lance-elliptic to ovate, more than 5 mm wide; corolla lobes light pink or occasionally white, less than 1.8× as long as wide, widest at ca. 0.6× their length, ± acute at apex _____ **Sabatia campestris**

HABITAT AND ASSOCIATED SPECIES

Sabatia arkansana is a plant of flat, seasonally wet microhabitats in shale and igneous glades in the eastern Ouachita Mountains and igneous batholiths of the Upper West Gulf Coastal Plain of central Arkansas. It appears to be restricted to small flat areas along the narrow floodplains of intermittent streams or along seepage areas within these glades. These habitats are typically wet in the winter and spring but usually become dry by July and remain so until the late fall. The substrate consists of thin soil over bedrock and of loose, weathered fragments of the same type as the local bedrock. No standing water was observed around the plants at the time of flowering.

Sabatia arkansana is known from glades with two different geologic substrates: shale from the Womble Formation and the igneous rock nepheline syenite (Fig. 6). The Womble Formation was deposited during the Middle Ordovician and consists of mostly black shale with thin layers of limestone, silty sandstone, and some chert (McFarland 2004). It is confined to the Central Ouachita Mountains physiographic province, a subsection of the Ouachita Mountains (Foti & Bukenhofer 1998). Large igneous intrusions of Late Cretaceous age outcrop in the Upper West Gulf Coastal Plain (Saline and Pulaski counties) and consist largely of nepheline syenite. These intrusions consist of light gray or bluish feldspathic and feldspathoidal igneous rocks in a batholith containing pendants of altered rocks of Paleozoic age, and are weathered locally to kaolin or bauxite (Haley et al. 1976; Gordon et al. 1958). These are the largest outcroppings of igneous rocks in Arkansas and are located within the Upper West Gulf Coastal Plain physiographic province, an area consisting of mostly unconsolidated surface geology of Cretaceous age and younger (McFarland 2004).

Associated species include *Talinum calycinum*, *Croton wildenowii*, *Croton capitatus*, *Croton monanthogynus*, *Euphorbia cyathophora*, *Bulbostylis capillaris*, *Fimbristylis autumnalis*, *Valerianella nuttallii*, *Calamintha arkansana*, *Allium*

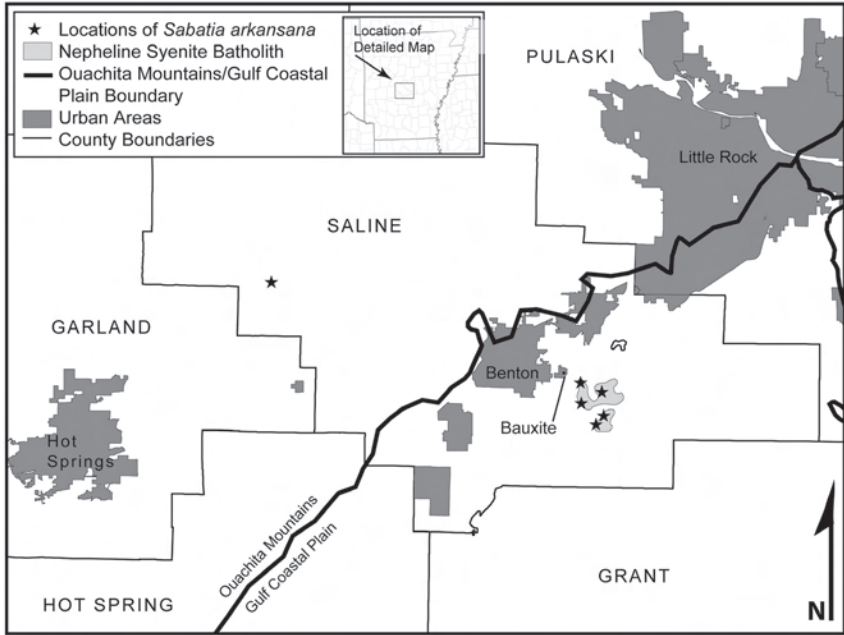


FIG. 6. Map showing the locations of collections of *Sabatia arkansana* in Saline County Arkansas and the nepheline syenite batholith southeast of Bauxite.

canadense var. *mobile*, *Hedyotis nigricans*, *Asclepias longifolia* var. *hirtella*, *Sedum pulchellum*, *Polygonum tenue*, *Aristida dichotoma* var. *curtissii*, *Digitaria cognata*, *Sporobolus ozarkanus*, *Panicum flexile*, *Chamaesyce missurica*, *Nemastylis nuttallii*, *Silphium laciniatum*, *Ptilimnium nuttallii*, *Amsonia hubrichtii*, *Aster oblongifolius*, *Eriocaulon kornickianum*, *Isoetes butleri*, *Grindelia lanceolata*, *Mimosa quadrivalis* var. *nuttallii*, *Astragalus distortus* var. *engelmannii*, *Selenia aurea*, *Ranunculus pusillus*, *Astranthium integrifolium*, *Minuartia patula*, *Eryngium yuccifolium*, *Spiranthes vernalis*, and *Nostoc* sp. (Nomenclature follows Kartesz 1999).

Of these associates, the following (given with their conservation status ranks) are tracked as elements of special concern by the Arkansas Natural Heritage Commission: *Valerianella nuttallii* (G1G2S1), *Nemastylis nuttallii* (G4S2), *Amsonia hubrichtii* (G3S3), *Eriocaulon kornickianum* (G2S2), *Chamaesyce missurica* (G5S2), and *Bulbostylis capillaris* (G5S3) (Arkansas Natural Heritage Commission 2002). *Valerianella nuttallii* and *Amsonia hubrichtii* are endemic to the Ouachita Mountains and Arkansas Valley of Arkansas and Oklahoma.

This new species of *Sabatia* is one of more than 15 endemic plant taxa from the Ouachita Mountains (including upland portions of the Arkansas River Valley and

the igneous batholith that outcrops in the Upper West Gulf Coastal Plain near the edge of the Ouachita Mountains in Saline and Pulaski counties, Arkansas). In addition to *V. nuttallii* and *A. hubrichtii*, these endemic taxa include *Amorpha ouachitensis*, *Carex latebracteata*, *Galium arkansanum* var. *pubiflorum*, *Liatris compacta*, *Hydrophyllum brownei*, *Polymnia cossatotensis*, *Monarda stipatatoglandulosa*, *Houstonia ouachitana*, and *Quercus acerifolia* (Zollner et al. 2005).

CONSERVATION STATUS

Though *S. arkansana* has been collected from a number of glade openings, all of these are components of only two larger glade complexes, the nepheline syenite complex near Bauxite and the Womble Formation (shale) complex near Owensville. Therefore it can accurately be stated that this species is known from just two sites in the world, both in Saline County, Arkansas. Glades with appropriate microhabitat in adjacent counties (Pulaski, Garland, and Montgomery) were searched in 2003 and 2004 and no new sites for *S. arkansana* were found. Because *S. arkansana* is an annual, population size fluctuates from year to year. Two shale glade openings at the Womble Formation site support populations of *S. arkansana*, which ranged from approximately 200 to more than 1000 individuals per opening from 2001 to 2004. Five glade openings in the nepheline syenite complex support populations on *S. arkansana*, which ranged from hundreds to thousands of plants per opening from 2001 to 2004.

These glades have historically been the sites of mines (in the case of the economically important nepheline syenite) and borrow pits for road fill material (in the case of the shale glades). The absence of significant past mining at the Womble Formation locality makes it an especially rare site among shale glades in the Ouachita Mountains. The open character of these glades is maintained in part edaphically by the thin soil and in part, at least historically, by fire. The absence of fire in recent years has allowed glades throughout the region to be invaded by woody plants, particularly eastern redcedar (*Juniperus virginiana*). This encroachment has led to the decline of many plant species dependent upon open glade habitat.

These factors, along with significant pressure from encroaching residential development, make these glades a high conservation priority. Several glades immediately west of the Womble Formation locality (and part of the same glade complex) have recently been destroyed for an addition to a large gated residential golf course community. Fortunately, the Arkansas Natural Heritage Commission was recently able to acquire and protect 136 acres (55 ha) that include the *S. arkansana* locality, several other glades, and associated woodlands and forest. Meanwhile, all of the known *S. arkansana* sites on the nepheline syenite batholith are being protected by joint efforts of the Arkansas Field Office of The Nature Conservancy and Alcoa Corporation.

ACKNOWLEDGMENTS

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