

Guide to Insect (and Other) Damage Types on Compressed Plant Fossils

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Title page image:

An example of Damage Type 38 on the host *Macginitiea wyomingensis* (Platanaceae) from the middle Eocene Green River Formation of Uintah County, Utah. Specimen courtesy of the Black Hills Institute of Geological Research, BHI 5329.

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Introduction

The fossil record of plant-insect associations traditionally has been investigated using informally described, distinctive types of insect-mediated damage, some of which have been assigned formal ichnogenic names. Although there is a rich literature exploring the broad spectrum of damage that insects have inflicted on vascular land plants in the fossil record, there has been minimal progress in developing a categorization of the varied types of insect- or mite- inflicted plant damage on fossil plant organs. Much of this insect-mediated damage is highly distinctive and typically exhibits features that are diagnosable in an unambiguous manner. However, much recent literature, from paleoecology to systematics, has shown the need for a comprehensive morphotyping system to provide an explicit characterization of the full spectrum of insect damage that occurs in compressed fossil floras. This Guide to Insect Damage Types on Compressed Plant Fossils is an attempt to fill this need, and to provide a formalized, accessible system that can be conveniently used, maintained, and updated.

Organization

This guide provides primary photographic documentation and definitions for damage types (DTs), which are discrete, repeatedly recognizable damage morphotypes occurring in the fossil record, recognized by the authors as of March 2007. In addition to definitive insect feeding damage, we also include some DTs from insect oviposition, mite feeding, and fungi, as these often are encountered in fossil floras, and they can be conveniently scored within the same overall system. This guide, and an ancillary database available from the authors, provide the following information.

The Damage-Type Approach and Definitions. Each of the 150 DTs in the current version of the guide is defined by a diagnostic suite of characters and is unambiguously separated from the other DT's. We include abbreviated definitions of each DT and its corresponding image; additionally, we provide extended, more complete and detailed DT definitions in a table at the end of the guide. Defining attributes of DTs include size, shape, pervasiveness, and position on the plant organ; stereotypy; internal structural features; type and extent of development of plant response tissue; and occurrence patterns of coprolites (preserved fecal pellets). An additional characterization of the damage is the mode of infliction by a particular functional feeding group (see next section below), such as by chewing, mouthpart stylet penetration, or consumption of internal tissues from within. These unique morphological and inferred behavioral features establish an exemplar, figured specimen for each DT, similar to the leaf morphotyping system used in paleobotany (Ash et al., 1999). Each distinctive DT is assigned a unique number that can be used in documentation, analyses, and interpretation of insect-mediated damage in the fossil record.

Functional Feeding Groups. Nearly all DTs have been assigned to a terrestrial arthropod functional feeding group (FFG), based on the mode of feeding, with the exception of two that are difficult to determine. Almost all DTs are insectan in origin, though some are mite galls (DTs 70, 107, 123 and possibly 127), a few are fungal or possibly bacterial in origin (DT 58 and possibly DTs 75 and 97), and the possibility remains that one type of folivory (DT12) may be partly attributable to herbivorous myriapods. The FFGs are well documented in the entomological literature (Coulson and Witter, 1984; Johnson and Lyon, 1991; Tovar et al., 1995), and consist of (1) external foliage feeding, (2) piercing-and-sucking, (3) galling, (4) leaf-mining, (5) seed predation and (6) oviposition. External foliage feeding, in turn, is subdivided into the four subgroups of hole feeding, margin feeding, skeletonization, and surface feeding. Although oviposition is not a type of feeding and rather represents the response of egg insertion into plant tissue, we are including it as a FFG because of its fossil record and its feeding-like use of plant tissue as a resource. A rare type of oviposition encountered in the fossil record is eggs on the leaf surface (DT67) that may not be associated with detectible surface damage, but which we are including in the ovipositional FFG because of its

interest. We have not found convincing evidence for stem or other types of boring in compression fossils, although inclusion in the future seems likely.

Specimens, Images, Repositories, Localities and Ancillary Data. The primary recognition of each DT is based on textual description, mentioned above, and a linked photo image of the exemplar specimen that illustrates as many of the key features as possible, such as plant-organ context and range of variation. The exemplar image of each DT will be occasionally updated based on better-preserved or more complete future material. In addition, a database (available from labandec@si.edu) provides additional documentation for each exemplar specimen, such as institutional repository, specimen number, locality, and stratigraphic provenance including rock formation and age. This database also lists museum cabinet and drawer designations for some DT specimens housed in certain institutional repositories. We anticipate a larger monographic work in which all the above data, as well as formal ichnotaxonomic treatment, is provided for a more complete account of each DT. The authors encourage feedback (to labandec@si.edu) to keep this guide as current as possible.

We emphasize that most of the DTs included here have been recognized (and numbered) sequentially from our own paleobiological research and undersample the total diversity of damage types in nature. Our studies have concentrated on Late Cretaceous and early Paleogene floras from the Western USA and Patagonia, Permian floras of the southwestern United States, and Middle Permian to Late Triassic floras from South Africa. We expect the number of fossil DTs to increase, and we welcome suggested, well-documented contributions from other working groups.

Host Specificity and Inferred Insect Culprits. A historically extensive entomological and agricultural literature has described and provided autecological data for a spectrum of insect damage on modern plants. Based on modern analog patterns of generalized to specialized types of insect feeding on plant hosts, as well as patterns of generalization to specialization of insect damage observed in fossil host plants, we have assigned for all DTs the host specificity values of 1 (generalized), 2 (intermediate) and 3 (specialized). A value of 1 represents confinement of the damage to a single plant species or perhaps more than one related species (monophagy). At the other end of the spectrum, a value of 3 represents catholic host plant consumption in which multiple, taxonomically unrelated plant hosts are consumed. A value of 2 represents an intermediate condition in which a group of phylogenetically related taxa is consumed, typically at intermediate levels of the taxonomic hierarchy (oligophagy). Assignment of host specificities, designated as HS, are provided in the long descriptions at the end of this guide. In the fuller database that we maintain (labandec@si.edu), we have indicated modern taxa that match the features of the fossil DTs, or we have provided modern analogs that closely resemble their fullest range of morphology.

Research Uses of this Guide

The guide stems from our first efforts to quantify the diversity of insect feeding damage on large field collections of compressed fossil leaves (Wilf and Labandeira, 1999), and its uses have since expanded. These can be divided into two broad approaches. The first is paleoecological characterizations of single bulk floras and their constituent species, or of time series of such floras. Such studies often involve the effects on herbivory patterns of either sudden events such as mass extinctions, or alternatively, of protracted environmental perturbation such as geologically gradual shifts in climate. A second approach consists of more detailed autecological, behavioral, or phylogenetic studies focusing on a single or a few selected associations of evolutionary interest. Within these two broad approaches, the following types of studies have been or currently are being undertaken, recognizing that some of these studies combine elements from both approaches.

1. *Responses of insect herbivores to past climatic change.* Two studies have documented shifts in temperature and moisture on a series of late Paleocene to middle Eocene floras from several intermontane basins of the western United States and the effects that this climatic change had on regional vegetational turnover and resulting patterns of herbivory (Wilf and Labandeira 1999; Wilf et al., 2001).

2. *Temporally focused patterns of plant-insect associations in selected plant or insect lineages within a phylogenetic context.* Detection of a highly stereotyped feeding pattern from the Late Cretaceous and Paleogene of North America revealed life-history patterns in a coevolved lineage of hispine beetles and their ginger hosts that persisted for 66 million years (Wilf et al., 2000). Also, a Bayesian-based phylogenetic analysis, calibrated to particular leaf mining DTs, allowed for inferences about the colonization history of a clade of leaf-mining moths on dicot host-plant clades (Lopez-Vaamonde et al., 2006).

3. *Autecological and behavioral aspects of fossil herbivore associations within diverse floras.* Broader life-history evaluations of many types of plant-insect associations include the middle Eocene Republic flora of Washington State (Labandeira, 2002), and the latest Cretaceous Hell Creek and earliest Fort Union floras of the Williston Basin (Labandeira et al., 2002).

4. *Dynamics of extinction and recovery in plant-insect associations.* Two major examinations of the effect of the end-Cretaceous extinction on plant-insect associations in the western United States (Labandeira et al., 2002; Wilf et al., 2006) have shown a regional extirpation of specialized insects and unusual food web dynamics during the early Paleocene recovery period.

5. *Biota-specific insect herbivore radiations and generation of associational diversity.* One example is the colonization and rapid diversification of leaf miners on numerous Late Triassic floras from the Molteno Formation of South Africa's Karoo Basin (Labandeira et al., 2005).

6. *Community paleoecology of plant-insect associations.* The examination of several floras from the Paleogene of Patagonia, Argentina, has provided primary plant-insect associational data for inferences regarding the roles that insect herbivores played in these plant communities, with implications for the early generation of South American plant and insect herbivore diversity (Wilf et al., 2005).

7. *Contrasts of the plant-insect associational record with the insect body-fossil record.* Evidence was mustered to demonstrate the overall robustness of plant-insect associational data over the insect body-fossil record for inferring the life histories of insect herbivores (Labandeira, 2007).

8. *The origin of herbivory.* Examples include the earliest known example of folivory, from the Early Carboniferous (Iannuzzi and Labandeira, 2007); and the distribution and intensity of insect herbivory on particular plant hosts across Early Permian riparian, interfluvial and adjacent environments from the Lower Permian of Texas (Labandeira and Allen, 2007). A more comprehensive analysis has evaluated Early Devonian to Late Triassic associations (Labandeira, 2006).

9. *Fossil food-web studies.* A study of the middle Eocene Messel aquatic and terrestrial food web has used predominantly trophic data from plants and insects for its construction, including numerous plant-insect associations from a broad variety of evidence (Dunne et al., in prep.).

Acknowledgements

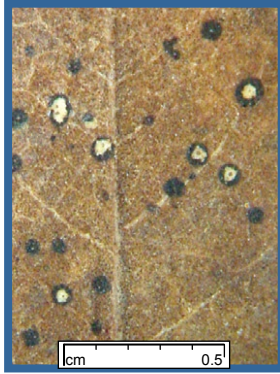
We thank Bonnie Miljour of the University of Michigan for producing the first version of this Guide and Robin Foster of the Field Museum for providing the original layout template. We are grateful to the following workers, who assisted in the detection and documentation of DTs: Laura Sarzetti of the University of Tucumán, Argentina (DTs 81, 115); John Anderson of the South African National Botanical Institute (DT100); Rose Prevec, of Rhodes University (DTs 106, 136); Ari Iglesias of the University of La Plata (DTs 113, 114, 116–118); Ellen Currano of Pennsylvania State University (DT 125); and Torsten Wappler of the Hessisches Landesmuseum (DTs 142–150). Other colleagues and assistants who participated in collecting the numerous floras that produced the DTs are thanked in the related publications cited below. We have received support from the National Science Foundation (Grants EAR-0230024 and DEB-0345750), National Geographic Society, Smithsonian Institution (Walcott Fund and Small Grants Award), and the American Philosophical Society. This is contribution 155 of the Evolution of Terrestrial Ecosystems consortium of the National Museum of Natural History.

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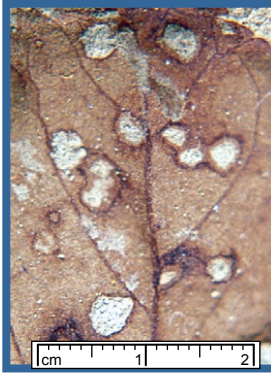
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Hole Feeding



DT01 Circular perforations, < 1 mm in diameter.



DT02 Circular perforations, 1 to 5 mm in diameter.



DT03 Polylobate perforations, 1 to 5 mm in diameter.



DT04 Circular perforations, > 5 mm in diameter.



DT05 Polylobate perforations, > 5 mm in diameter.



DT06 Symmetrical damage pattern on both sides of one or more primary veins; circular perforations.



DT07 Curvilinear to rectilinear elongate perforations.



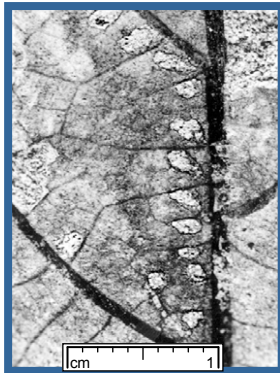
DT08 Parallel sided, rectilinear or curvilinear; length / width ratio > 2.5.



DT09 Scattered, comma-shaped to elliptical perforations often near margin.



DT10 Excised tissue ring with loosely attached central disc.



DT50 Linear series associated with 1° or 2° veins.



DT51 Overlapping slots forming large angulate holes.



DT57 At divergence of 2° veins from 1° veins.



DT63 Major vein suspended by leaf removal on both sides.



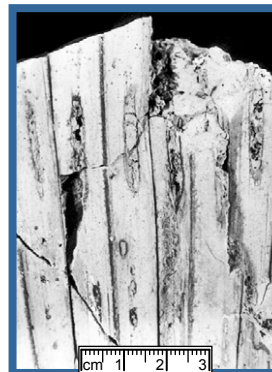
DT64 A linear pattern of perforations adjacent to leaf margin.



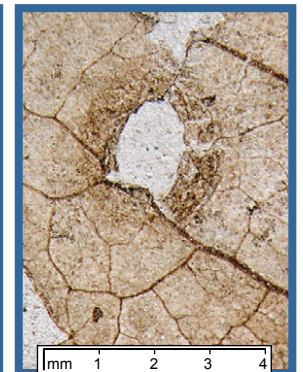
DT68 1° or 2° vein, removed.



DT78 Entire tissue in three or more intercostal areas that is (almost) completely removed.



DT98 Symmetrical damage pattern on both sides of one or more primary veins; ellipsoidal perforations.



DT113 Small, round, wide rim of blotched, veined tissue.

Hole Feeding (continued)



DT126 Ellipsoidal holes connected by extensive dark necrotic tissue.



DT148 Circular holes with a broad flange of reaction tissue, often extending to enveloping polylobate area.

Margin Feeding



DT12 Circular, shallow to deep excision of leaf margin, < 180 degrees of arc.



DT13 Excision of leaf apex, including primary vein.



DT14 Excision of leaf to a primary vein.



DT15 An excision that is deeply incised or expands toward a primary vein.



DT26 Extensive removal of interveinal tissue; veinal stringers or flaps present.



DT81 Almost or perfectly circular, > 180° of arc; can range from a cusped excision to a hole.



DT142 Cusped margin feeding with a very broad rim of transverse lineations.



DT143 Three or more serial, cusped margin excisions, separated by small leaf-margin segments.

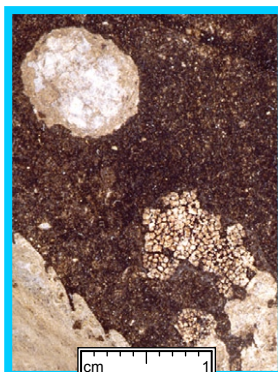
Skeletonization



DT16 Interveinal tissue removed; reaction rim poorly developed.



DT17 Interveinal tissue removed; reaction rim well developed and/or thickened.



DT18 Adjacent to large circular holes.



DT19 Broad, rectangular skeletonized area.



DT20 Elongate, curvilinear to rectilinear.



DT21 Highest orders of venation removed.



DT22 Linear, elongate patches parallel to leaf margin or primary veins.

Skeletonization (continued)



DT23 Very narrow, multiple, subparallel, curvilinear swaths.



DT24 Ovoidal; adjacent to 1° or 2° veins.



DT56 At leaf base, between two or more basal veins.



DT61 Elongate, adjoining and following 1° or 2° venation.



DT79 Thin zone of ~ constant width, adjoining and following 1° and 2° veins.

Surface Feeding



DT25 Elongate, narrow surface abrasion of constant width.



DT27 Linear surface abrasion parallel to 1° vein.



DT28 Abrasion between parallel veins with ragged margin & reaction rim.



DT29 Removal or abrasion of surface tissues with a weak reaction rim.



DT30 Removal or abrasion of surface tissues with a distinct polylobate reaction rim.



DT31 Removal or abrasion of surface tissues with a distinct circular to ellipsoidal reaction rim.



DT75 V-shaped necrotic area, distinct reaction rim; widens to leaf margin.



DT82 Polylobate window feeding, ~ symmetrical about 1° or 2° vein.



DT97 U-shaped necrotic area; distinct reaction rim ~ parallel to fasciculate venation.



DT103 Elongate window feeding (sub)parallel to major venation.

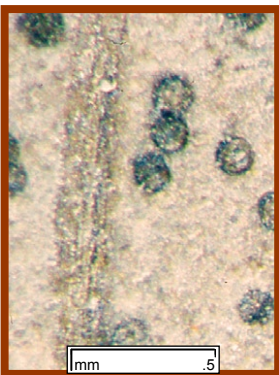


DT130 Window feeding parallel to 2° veins; occupying 1 or more broad interveinal areas of damage.

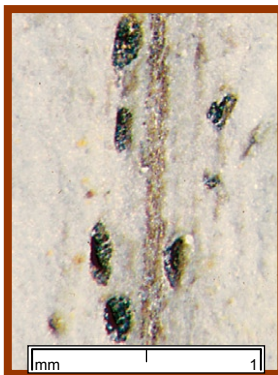
Piercing & Sucking



DT46 Circular punctures < 2 mm diameter; central depression.



DT47 Circular punctures < 2 mm diameter; with central dome.



DT48 Elliptical punctures < 3 mm maximum diameter.



DT53 Ellipsoidal to circular impressions on 1° veins.



DT77 Convex, circular scales or their impressions, with concentric ridges.



DT86 Round scale; 1–2 mm diameter; outer rim surrounds internal area of concentric beadlike lobes.



DT118 Pattern of punctures forming concentric or eccentric circles.



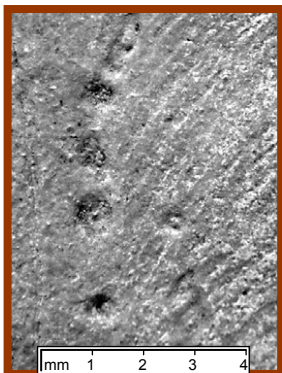
DT128 Ellipsoidal scale impressions with roughened surface, apical notch, marginal trough, & pustulose interior.



DT132 Small (< 1.1 mm long), thick ellipsoidal scars with eccentric lineations; between parallel veins.



DT133 Circular structures with roughened surfaces; on parallel veins.



DT138 Linear row of punctures along or adjacent to a primary vein.

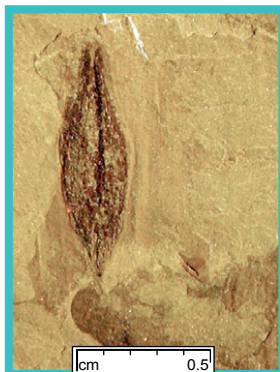
Oviposition



DT54 An arcuate pattern; in multiple, subparallel rows.



DT67 Clusters of overlapping, subparallel-oriented, ellipsoidal eggs.



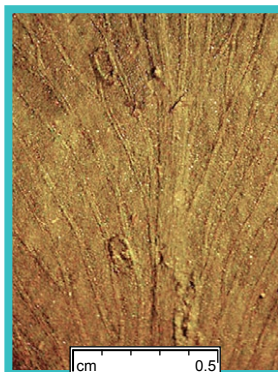
DT72 Lenticular to oval slits parallel to stem vasculature.



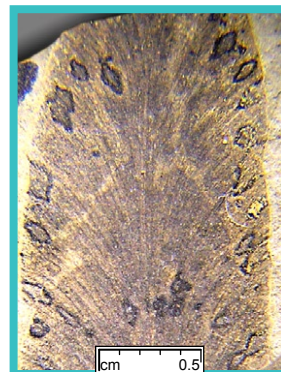
DT76 Oriented along or in 1° leaf vein.



DT100 Lenticular-ovoid foliar scars in compact clusters or multiple, adjacent linear files.



DT101 Lenticular-ovoid foliar scars occurring singly or unpatterned and scattered.



DT102 Linear series at leaf margin of lenticular-ovoid marks, each parallel to 2° veins; distinctive callus.

Oviposition (continued)



DT108 Ellipsoidal to polylobate oviposition scars on stems; veins deformed.



DT134 Linear, elongate, carbonized marks longitudinally centered on a 2° parallel vein.



DT136 Mid-lamina scars connected by reaction-front line, with necrotic tissue damage distally.



DT137 Triangular to lenticular, elongate scar oriented transverse to primary midvein.

Mining



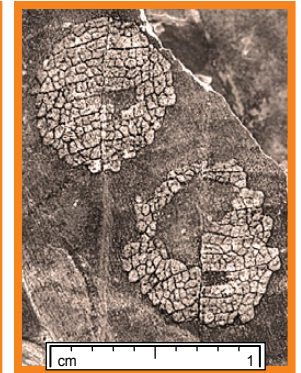
DT35 Blotch; rounded margin and bearing a central chamber; coprolites often present.



DT36 Blotch; no central chamber.



DT37 Blotch; with internal frass-laden serpentine phase.



DT38 Circular, "skeletonized," areas (leaf cases); often many per leaf, with discrete size increases.



DT39 Linear, between parallel veins; small, dispersed, spheroidal coprolites.



DT40 Semilinear, frass-laden, smooth and rimmed margin; enlarged terminal chamber.



DT41 Serpentine; initially threadlike, then tortuous; undulatory frass packed; margins smooth, increasing width.



DT42 Linear; skeletonized tissue, frass absent; expanding width; ragged margin.



DT43 Short, serpentine, with linear margin; solid frass; expanding width.



DT44 Long, serpentine; frass undulatory, confined to median 1/4; terminal chamber circular.



DT45 Serpentine; discrete width expansions; frass packed in sections; round oviposition site.



DT59 Linear; oviposition adjoining 2° vein, then following 1° vein; 1 - 1.5mm width; ends in large ovoidal



DT60 Linear, frass absent; rapidly widening at leaf base, parallel to 1° veins; reaction rim, terminal



DT65 Long; initially linear, then serpentine and rapidly expanding; terminus blotch-like.

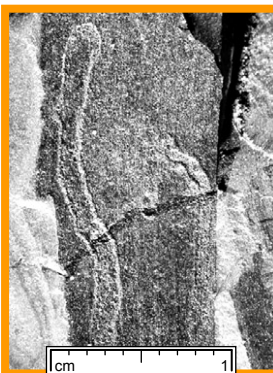
Mining (continued)



DT66 Linear; early to middle portion coiled; evenly-spaced, with particulate fecal pellets.



DT69 Circular blotch; ellipsoidal, dispersed coprolites; outer reaction rim.



DT71 Linear, gradually widening, between 1° parallel veins; dispersed spheroidal pellets.



DT88 Full-depth, elongate blotch with packed coprolites and rounded margin; primary veins distorted.



DT89 Spiral petiole mine; frass in periodic thick clumps.



DT90 Linear, minimal width increase; ragged-irregular margin; frass intermittent, thick, particulate; terminal chamber.



DT91 Robust; early part intestine-like, no pellets; later part serpentine, ellipsoidal pellet boluses in mid-70% of 0.5 - 1.1 mm wide mine.



DT92 Medium length, undulatory, determined by 1° & 2° veins; pellets in center half to full mine width.



DT93 Six phases, serpentine; first & last dispersed meniscate coprolites; middle 4 sinusoidal, angulate turns within 0.1 - 1.2 mm wide mine.



DT94 Full-depth, serpentine, rounded sides; broad loops cross all veins; minimal width increases.



DT95 Three-sectored: first hairline; second much wider, no pellets; third very wide, with packed ellipsoidal pellets in chains.



DT96 Linear, 0.1-1.5 mm wide, confluent with parallel veins; packed dense frass; mostly continuous 3-D tube, increasing width.



DT99 Thick, linear, robust; on foliar margin; minimal width change; dense meniscate frass throughout.



DT104 Sinusoidal, long, crisscrossing; hairline trail 0.1 mm in central 1/10th mine; thin stringers between frass clumps.



DT105 Serpentine, parallel sided, thin reaction rim; frass absent; crossing 2° and 3° veins.



DT109 Short, serpentine, threadlike; frass probably solid; all significant veins avoided.



DT111 Serpentine; thick frass; penultimate phase within 2° vein; terminus bulb-like chamber.



DT129 Linear, dumbbell-shaped; colinear with parallel-veined leaf; central frass trail and reaction rim.



DT131 Elongate, spindle-shaped, striate or scaly cases impressed on leaf surface.

Mining (continued)



DT139 Serpentine, cutting across 2° veins; with prominent, solid, thick, intestiniform frass most of mine width.

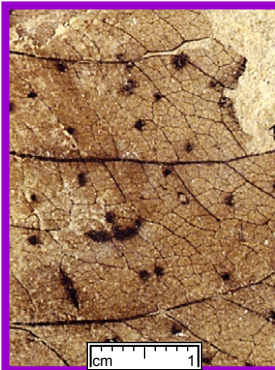


DT141 Thin, zigzag, entirely laden with frass; transverse path on sphenostem just below nodes.

Galling



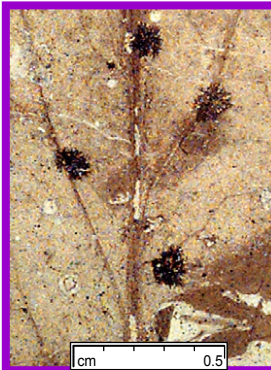
DT11 Circular or polylobate; minimal central tissue, surrounded by a wide rim of thick tissue.



DT32 Circular to ellipsoidal; avoiding major veins.



DT33 Circular to ellipsoidal; on 1° veins.



DT34 Circular to ellipsoidal; on 2° veins. middle 70% of 0.5 - 1.1 mm wide mine.



DT49 Circular, large fusanized core separated from distinct outer rim by 1 to 3 mm.



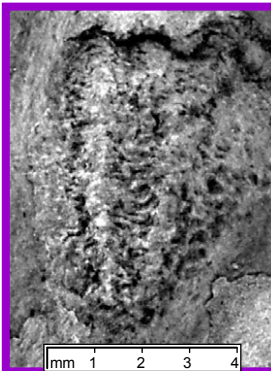
DT52 Circular, with fusanized tissue in radiating partitions.



DT55 On petiole.



DT62 Flat, thickened, circular, and pockmarked pustules in chains.



DT70 Initially leaf thickened, maturing to a multilobate structure of an entire leaf; pockmarked surface.



DT80 Small, hemispherical; thoroughly carbonized; diameters ~ 0.1 - 1.0 mm; 1° and 2° veins avoided.



DT83 Circular, avoiding veins; raised fusain core with 1 - 6 small central holes between frass clumps.



DT84 Elliptical, on 1° vein; 2X long as wide; elongate fusain core thinner than margin; small peripheral holes.



DT85 Elongate, elliptical, striated; centered on major veins, especially a midvein; l/w ratio ~ 4.0.



DT87 On a twig, branchlet or short shoot.



DT107 Nonlobate, thickened leaf; pockmarked cluster of spheroidal chambers ~0.1 to 0.2 mm diameter.



DT110 Large; on 3° veins, ovoidal-circular; central chamber sharply separated from thick carbonized brim.

Galling (continued)



DT112 Flat, ovoidal; rimmed margin with sinuses; inner surface convoluted, faintly concentric; 1° veins avoided.



DT115 Ellipsoidal; long axis following parallel veins; thick, hardened outer tissue.



DT116 Circular, columnar, deeply attached; thin outer wall; contents a chamber enveloped by amber or sediment.



DT117 Small, spheroidal structures on 1°, paralleling vein; dark circular marks within and prominent outer rim. sediment.



DT119 Elongate (> 2X width), lobate, expanding distally, pedicellate; on deformed 2° veins.



DT120 Circular to polylobate, attached to 1° or 2° vein; thick, woody outer rim of radiate fusain; inner area disrupted, planar, and veined.



DT121 Ellipsoidal, sessile bud gall from branchlet; bulbous base, beaklike apex with emergent processes.



DT122 Medium sized, smooth, ellipsoidal galls oriented parallel to and often distorting veins of narrow leaves.



DT123 Cupped, thickened, lobed pinnules; undulate surface of galled tissue often encompassing entire pinnule.



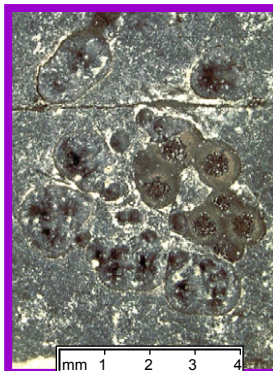
DT125 Uniformly thick, small circular to variably large polylobate galled tissue between major veins; marginal rim.



DT127 Ellipsoidal-spheroidal galls extending beyond leaf margin; with a botryoidal to roughened surface.



DT135 Small, isolated or joined galls up to 2.0 mm in diameter; on woody axis typically occurring in rows.



DT144 Multiloculate; dark inner core, surrounding smooth surface and circular margins; often fused.



DT145 Spheroidal; large central chamber surrounded by thick wall and second tissue layer; outermost layer thin.



DT146 Large, unilocular, hemispherical, with smooth surface and thickened base; on midrib.



DT147 Small, irregular shape, thickened; with internal partitions representing continuation of tertiary venation.



DT149 Cylindrical to ovoidal, interveinal; with prominently ribbed exterior and short, pedunculate base.



DT150 Elongate, attached to 2° veins; thick wall with transverse structure, smooth surface and acute tip.

Seed Predation



DT73 Lenticular or ellipsoidal perforations of seed central body > 0.5 mm diameter.



DT74 Circular penetrations of seed central body < 0.5 mm diameter.



DT124 Major removal of nutritive or embryonic tissues from 3-D seed.



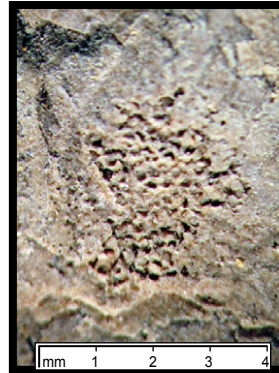
DT140 Removal of seed tissues at attached end of wind-dispersed seed; prominent surrounding ovoidal scar.

Fungal



DT58 Blotches with diffuse to sharp reaction front, disrupted, planar, and veined.

Incertae Sedis



DT106 Irregular areas of roughened epidermal tissue; surface pockmarked by tiny circular-ellipsoidal cavities.



DT114 Necrotic tissue strip along leaf-margin; distinct reaction front abutting unaffected foliar tissue.

Hole Feeding

- 1 Small-sized circular perforations, less than 1 mm in maximum diameter. HS=1
- 2 Medium-sized circular perforations, between 1 mm and 5 mm in maximum diameter. HS=1
- 3 Medium-sized, polylobate perforations between 1 mm and 5 mm in maximum diameter. HS=1
- 4 Large-sized, circular perforations, greater than 5 mm in maximum diameter. HS=1
- 5 Large-sized, polylobate perforations, greater than 5 mm in maximum diameter. HS=1
- 6 Bud feeding: an approximately symmetrical pattern of damage on either side of one or more major leaf veins, circular perforations. HS=2
- 7 Curvilinear to rectilinear elongate holes that lack parallel sides. HS=1
- 8 Slot feeding: rectilinear to less commonly curvilinear holes with parallel sides, having a length to width ratio greater than 2.5. HS=2
- 9 Dense pattern of comma-shaped to elliptical holes greater than 2 mm scattered throughout the leaf blade, but frequently occurring only near the margin. HS=2
- 10 A ring of excised tissue with a central disc of tissue loosely attached. HS=2
- 50 A linear series of variably sized holes adjacent to primary veins, occurring on one, both, or alternating sides of the vein. HS=2
- 51 Slots that overlap into a large, angulate, central area, and including adjacent slots associated by pattern. HS=2
- 57 A pattern consisting of three or more holes lodged at the divergence point of secondary veins from primary veins. HS=2
- 63 A major vein suspended for some distance (more than three times the inferred vein width) on both sides by extensive leaf removal. (The condition is opposite to DT68.) HS=2
- 64 A series of three or more small to medium (<5.0 mm diameter) circular holes in a linear pattern associated with the leaf margin. HS=2
- 68 Vein feeding: removal of primary or secondary vein tissue with adjacent reaction tissue, parallel to removed area. (This condition is opposite to DT63.) HS=3
- 78 A pattern in which the tissue of three or more adjacent or nonadjacent intercostal areas (region between secondary veins) is completely removed to varying extent, often with elongate areas of removal greater than twice their width. HS=1
- 98 Bud Feeding: an approximaely symmetrical pattern of damage on either side of one or more major leaf veins; ellipsoidal to elongate perforations. HS=3
- 113 Central roundish hole, ~ 1.0 to 2.0 mm diameter, with a distinct edge, surrounded by a wide rim from 0.5 to 1.0 times that of the enveloped hole diameter; characterized by darkened, blotched foliar tissue with venation preserved. HS=1
- 126 Ellipsoidal holes; 1-4 mm in longest dimension; connected by extensive, surrounding and intervening, dark necrotic tissue. HS=3
- 148 Circular holes from 2 to 5 mm diameter with a broad brim of reaction or polylobate necrotic tissue, often extending considerably into the lamina (by a few hole diameters). HS=1

Margin Feeding

- 12 Isolated, approximately circular, shallow to deeper excision of a leaf margin for less than 180 degrees of arc: *Phagoptyichnus ekowsii* (Amerom, 1966). HS=1
- 13 Apex feeding; excision of a leaf, leaflet or pinnule apex resulting in the clipped terminus of a primary vein and associated tissue. HS=1
- 14 Excision of the leaf blade extending to a primary vein, typically a midvein. HS=1
- 15 A deeply incised or otherwise trenched excision of the leaf blade that expands inwardly from the leaf margin. HS=2
- 26 Free feeding; extensively and completely removed interveinal tissue surrounded by remaining veinal stringers or occasional flaps of laminae. HS=2
- 81 Near-perfect or perfect circular arc of leaf-margin excision, subtending more than 120 degrees of arc, and merging into hole feeding internally within the blade that consists of a completely or incompletely constructed circular hole. HS=1
- 142 Cusate margin feeding with a broad, thick rim of reaction tissue, probably fungally affected tissue, with lineations oriented approximately perpendicular to cut edge. HS=3
- 143 Three or more serial, cusate margin excisions consisting of three or more adjacent cusps separated by a short segment of leaf margin. HS=1

Skeletonization

- 16 Removal of interveinal tissue resulting in retention of some vein network but with a surrounding reaction rim poorly developed or barely evident. HS=1
- 17 Removal of interveinal tissue, with some vein network remaining; reaction rim enveloping skeletonized area well developed and often thickened. HS=1
- 18 Skeletonized tissue adjacent to or otherwise associated with large circular holes. HS=2
- 19 Variously oriented, broad, elongate rectangular patches of skeletonized tissue characterized by a length-to-width ratio greater than 2.5. HS=2
- 20 Elongate, curvilinear to rectilinear strings of skeletonized tissue representing removal of interveinal tissue. HS=2
- 21 Highest orders of venation removed; broad swaths of interveinal tissue are absent. HS=2
- 22 Linear and highly elongate, parallel to the leaf margin or midvein, and having a length-to-width ratio greater than 5. HS=2
- 23 Multiple, subparallel, curvilinear swaths, each separated by about 1 mm, resembling a fingerprint. HS=3
- 24 Two or more ovoidal to circular skeletonized areas adjacent to primary or secondary veins. HS=2
- 56 A skeletonized area or areas occurring at the base of a leaf between two or more basal veins. HS=2
- 61 Highly elongate, continuous or patchy, unmined skeletonized zone that adjoins and follows one side of the primary and secondary venation. HS=3
- 79 A thin skeletonized zone of relatively constant width that adjoins and exactly follows both sides of the primary and secondary venation. HS=2

Surface Feeding

- 25 Elongate surface abrasion of constant width, often threadlike and branched. HS=2
- 27 A long, linear swath of surface abrasion that is greater than 2 mm in width and (sub)parallel to a primary vein. HS=3
- 28 Strip feeding: surface abrasion between secondary veins delimited by a ragged margin and discernable reaction rim: *Cephaloleichnites strongi* (Wilf et al. 2000). HS=3
- 29 Generalized surface abrasion or window feeding of varied sizes and shapes characterized by poorly developed reaction rims. HS=1
- 30 Surface abrasion or window feeding, characterized by a polylobate shape and a well developed reaction rim. HS=1
- 31 Surface abrasion or window feeding characterized by a circular to ellipsoidal shape, a variable diameter, and a well-developed but not overly thick reaction rim. HS=1
- 75 Irregularly distributed, larger surface penetrations of the central seed body; each mark greater than 0.5 mm in longest dimension, and consisting of ellipsoidal to lenticular disruptions of seed-coat surface that contain disorganized material within. HS=3
- 82 Dispersed smaller surface penetrations or pits of the central seed body; consisting of circular perforations less than 0.5 mm in diameter, and contrasting with adjacent seed-coat microstructure. HS=2
- 97 A region of U-shaped necrotic tissue bordered by a distinct reaction rim that is approximately parallel to secondary (often fasciculate) venation; narrows toward the axial leaf region and has tissue within appearing disorganized. HS=2
- 103 Elongate, parallel-sided; surface abrasion or window feeding, characterized by a length-to-width ratio greater than 2.5 as in DT8, but with tissue within; typically parallel or subparallel to longitudinal venation. HS=1
- 130 Elongate surface abrasion or window feeding parallel to secondary veins, similar to DT78 in overall aspect but often consisting of one or more interveinal regions of damage; width: length ratio > 2.5. HS=1

Piercing & Sucking

- 46 A concave styletial puncture into the veins, mesophyll or other leaf tissue, less than 2 mm in circular diameter, and characterized by an infilling of dark, carbonized material and a central depression; often abundantly distributed in clustered or random patterns. HS=3
- 47 A convex styletial puncture into the veins, mesophyll or other leaf tissue, less than 2 mm in circular diameter, and characterized by an infilling of dark, carbonized material and a central dome; often abundantly distributed in clustered or random patterns. HS=3
- 48 A concave or convex elliptical puncture into the leaf tissue, less than 3 mm in maximum diameter, and characterized by an infilling of dark, carbonized material and a variable central region; often abundantly distributed and clustered in or along vascular tissue. HS=3
- 53 Large ellipsoidal impressions of scale insects on the primary veins of leaves, with a length-to-width ratio approximately 1.25, and 3 to 10 mm in maximum diameter; unaltered veins are visible through the scale, indicating the absence of galled tissue. HS=3
- 77 Small, convex, circular, scale-insect structures on foliar surfaces, approximately 1.0 mm in diameter, and consisting of one or more concentric ridges. (It is possible that this DT may, in part, be a body fossil.) HS=1
- 86 Subrounded scales, each from about 1 to 2 mm in diameter with a raised outer rim surrounding system of nearly-concentric internal features with less relief than outer rim; the latter ornamented with diminutive beadlike lobes or impressions of such structures. HS=3

- 118 Highly patterned piercing-and-sucking marks arranged into one to three concentric (occasionally eccentric) circles ranging in total diameter from 3 to 5 mm and consisting of about 20 to 35 punctures for each circle series. HS=3
- 128 Distinctive ellipsoidal to spheroidal scale-insect impression marks on epidermal tissues causing a roughened surface and ranging from 4.0 to 7.0 mm in length and 2.0 to 4.0 mm in width, with long axis oriental parallel to venation; a distinctive marginal trough and an apical notch are always present; parallel to venation; faint enlargement scars (up to 5) of nymphal stages often observable. HS=3
- 132 Distinctive, ellipsoidal scar compressions in interveinal areas, with robust eccentric lineations; 0.2 x 0.3 to 0.7 x 1.1 mm; or corresponding scale insect carapace with greater length-to-width ratio of ~ 4; ranging from 0.2 mm wide to 1.0 mm long; surface appearing glassy. HS=3
- 133 Circular to somewhat ellipsoidal impressions spanning 1 to 5 secondary parallel veins, with distinctive color and texture; ranging in maximum diameter from 0.2 to 1.2 mm; similar to DT53 but significantly smaller. HS=3
- 138 A row of punctures along or immediately toward the side of a midrib or other primary vein consisting of 3 or more round or ellipsoidal punctures, sometimes associated with a major vein divergence. HS=2

Oviposition

- 54 Lenticular to ovoidal disruptions of surface tissue, each a few mm long, surrounded by a periphery of prominent scar tissue and arranged into an arcuate row of a few to about 20 such scars with no preferred orientation on the leaf; typically deployed into multiple subparallel rows that indicate a common pivot point of an ovipositing insect. HS=3
- 67 An overlapping cluster of elongate eggs, each of which has a length-to-width ratio of 3:1, and whose long axes are oriented in a subparallel fashion. HS=3
- 72 Lenticular to broadly oval, ellipsoidal, rarely circular; oviposition insertions oriented parallel to the axis of a stem, typically with a distinct inner region surrounded by a scar of callus tissue. HS=2
- 76 Single occurrences or linear rows or of ovoidal to cuneate scars oriented along or in primary vein of a leaf. HS=1
- 100 Lenticular to ovoidal oviposition scars on leaves arranged as compact circular to ellipsoidal clusters, or as one or multiple and adjacent linear files that are parallel or inclined to venation. HS=2
- 101 Lenticular to ovoidal scars with prominent reaction rims that occur singly or in an unpatterned and dispersed manner over the leaf surface, and thus are not arranged in clusters of arcuate or linear rows. HS=2
- 102 Linear series of lenticular or ovoidal oviposition marks with thick reaction rims occurring at the leaf margin or toward its midveinal axis; each scar oriented parallel to a venation of diverging, subparallel secondaries. HS=2
- 108 Large, ellipsoidal, circular to more irregularly polylobate oviposition scars on stems, often reaching 0.8 mm in maximum dimension, characterized by subdued reaction rims and an internal structure of deformed vascular strands and other tissues. HS=1
- 134 Distinctively thin, linear and small oviposition marks forming carbonized impressions; longitudinally centered on and oriented along a secondary parallel vein, ranging from about 0.05 wide by 0.6 to 0.9 mm long. HS=3
- 136 Oviposition on mid-blade, distal of midrib, with necrotic tissue damage distal from a curvilinear reaction front linking oviposition scars; inner tissues near midrib normal. HS=2
- 137 Oviposition on midvein or primary vein; elongate triangular to lenticular scar (aspect ratio>3.0) oriented transverse to veinules or other vascular and structural tissue; characterized by a penetration point and an associated linear extension. HS=1

Mining

- 35 A blotch mine typically rounded along the outer margin, with or without small dispersed coprolites, and containing a central chamber. HS=3
- 36 A blotch mine lacking a central chamber, often containing dispersed, small ellipsoidal or spheroidal coprolites. HS=3
- 37 A blotch mine bearing an overall ellipsoidal to elongate polylobate shape, containing a variously positioned internal serpentine phase that often has transversely oriented frass. HS=3
- 38 Circular mined areas, appearing skeletonized, often as many as 10 to 15 per leaf, that have discrete size increases in diameter and frequently are preserved with an inner rounded or angular case of modified leaf tissue. HS=3
- 39 Indistinctly mined regions between parallel veins encompassing one or more intervening veins, and consisting of small, spheroidal, dispersed coprolites. HS=3
- 40 A mine having a semilinear trajectory, characterized by a linear margin with a distinct reaction rim; and a terminal chamber that is about 10 times wider than the previous linear phase; entire mine is filled with thick and solid frass. HS=3
- 41 A mine having a very long and highly coiled trajectory, internally containing an undulatory trail of particulate frass that occupies most of the mine width; the mine margin is relatively smooth; mine width increases noticeably from the oviposition site to the terminus and is initially threadlike. HS=3
- 42 A mine of medium length and a rapidly increasing width that generally ascends a secondary vein, and is characterized by an irregular margin, absence of frass, and the presence of tertiary and lower-ranked venation. HS=3
- 43 A mine of relatively short length and with a linear margin, consisting of a solid frass trail occupying the entire mined area; expands in width from an early narrow phase to a preterminus phase of about 1.0 mm. HS=3
- 44 A long mine that is serpentine but not tightly coiled; the frass is tightly undulatory and confined to median one fourth or less of the mine width; terminal chamber is circular or otherwise rounded. (This mine was formerly assigned to "Serpentine D".) HS=3
- 45 A mine of medium length, featuring an irregular margin, rapid and discrete width expansion, frass packed in sections, and the presence of tertiary venation; the oviposition site and latter phases (the last possibly ending in a terminal chamber?) are well developed. HS=3
- 59 A distinctive linear mine that adjoins and follows the secondary-to-primary venation closely; oviposition is adjacent a secondary vein and the mine, initially of thin width, then follows by minimal width increases to an ending phase of 1.0 to 1.5 mm width; it ends in a sudden, large expansion to 5.0 to 10.0 mm as a large ovoidal or ellipsoidal terminal chamber. HS=3
- 60 One to a few linear, rapidly widening mines originating at the leaf base in the angulate areas between adjacent, major palmate veins; subsequent trajectory parallel to palmate venation; a thick reaction rim is present and the mine ends in a large terminal chamber. HS=3
- 65 Medium- to large sized, but conspicuous mines, often greater than 30 mm in length and up to four per leaf; typically linear, some initially coiled, with a rapidly expanding diameter, and often becoming blotch-like in the terminal phases. HS=3
- 66 A mine in which the early to middle portion is coiled and contains an evenly-spaced, particulate train of fecal pellets; terminal phase or phases unknown. HS=3
- 69 Circular to a somewhat elliptical blotch mine from 1.0 to 5.0 mm in diameter; containing tiny, ellipsoidal, dispersed coprolites and a well developed, outer reaction rim. HS=3
- 71 Elongate, parallel-sided mines that are mostly bounded by major parallel veins, with gradual width increase and lodged in mesophyll; fine venules occasionally consumed; frass particulate and consisting of dispersed spheroidal pellets, often arranged in a meniscate pattern. HS=2

- 88** A full-depth, elongate-ellipsoidal, blotch mine with a linear to gently rounded margin and distorted internal primary veins; the inner edge of the mine has a mass of densely packed frass (often to one side) consisting of spheroidal fecal pellets and more amorphous matter, in contrast to the majority of mines, which lack such frass. HS=3
- 89** A spiral leaf mine occurring around a leaf petiole, with frass preserved as thick and clumped masses. HS=3
- 90** A linear mine of minimal width increase with an irregular and sometimes ragged margin and reaction rim present; the terminal chamber, when present, lobed and elongate and up to 2 to 3 times the width of the linear portion of mine; frass, when present, thick and particulate and developed in some sections of the mine. HS=3
- 91** Robust mines ranging from tightly sinusoidal (intestinform) to gently serpentine in trajectory and widths from 0.5 to 1.1 mm; veins of all ranks have minimal effect on mine course and tertiary veins are evident through the mine and control the mine margin; frass not present in early phases and often occurs in certain sections of the mine, consisting of small ellipsoidal-circular pellets occupying central 70% of mine width; a distinct terminal chamber probably not present. HS=3
- 92** A medium length, strongly folded, serpentine mine consisting of modest width increases, whose trajectory is strongly influenced by primary and secondary veins; containing particulate frass occupying the center half to full width of the mine; terminal chamber subrounded with dispersed frass pellets about 2 to 3 times the width of the previous phase. HS=3
- 93** A serpentine, often tightly folded mine consisting of at least six discernible phases; initial phase with a meniscate-sinusoidal frass trail, rapidly changing into a sinusoidal condition with distinctive angulate turns and occupying the entire width of mine from 0.1 to 1.2 mm; ultimate phase characterized by dispersed, unclustered or faintly meniscate frass; a characterizable terminal chamber not evident. HS=3
- 94** A full-depth, serpentine mine with rounded sides; deployed as broadly looping swaths that cross all, including major, veins; length extending up to 90.0 mm and width lacking discrete size increases, ranging from 1.0 to 4.0 mm; reaction rim variably developed; all nonepidermal tissues frequently removed, but earlier portions may have one or two epidermal layers enclosing dispersed frass; often terminating in a proportionately large, polylobate area. HS=3
- 95** A mine divided into three sections with distinctive frass, beginning with a thin hairline mine after egg hatching, followed by a much wider mine in which one tissue layer is consumed by a fluid feeder (no pellets), followed by a considerably wider mine of discrete, numerous, packed, ellipsoidal pellets; the third section is consumed by a solid-tissue feeder and is subdivided into multiple phases as indicated by initiation and termination of pellet stringer chains; terminal chamber not preserved. HS=3
- 96** Linear leaf mine, ranging from 0.1 mm to 1.5 mm in width; occupied by dense frass, preserved three-dimensionally as a continuous tube, oriented subparallel or parallel to a parallel-veined leaf; early instars depositing a tube of packed frass, later instars with more idspersed fecal pellets. HS=3
- 99** Thick, robust mine with minimal width increase occurring on the margin or edge of pinnule; entire mine width occupied by dense frass, for which there is some indication of meniscate packing. HS=3
- 104** Highly sinusoidal, long to very long, occasionally crisscrossing mine, mostly 1.5 to 2.0 mm wide with a thin (about 0.1 mm), initially a hairline, frass trail often with longitudinal ridges; frass trail occupying central 1/10th of mine; early phases represented by occasional segments or amorphous and variably shaped clumps of unpelleted frass connected by thinner stringers; later stages of frass mostly a continuous film with occasional but minor accumulations; terminal chamber poorly developed. HS=3
- 105** A serpentine mine with several folds, lacking frass, ranging from 0.1 to 1.0 mm in width and crossing secondary and tertiary venation; mine parallel sided and bearing a thin reaction rim. HS=3
- 109** Small, very thin, relatively short, threadlike, serpentine mine 0.01 to 0.10 mm in diameter, from 1.0 to 3.0 cm long; avoiding secondary and tertiary veins; probably with solid frass occurring along entire mine width and length. HS=3
- 111** Serpentine mine ranging from 0.5 to 2.0 mm in thickness, with a black, thick (fusanized) frass occupying the entire mine width; penultimate phase occurring within a secondary vein; terminus consisting of a modest circular, bulb-like chamber about 5 mm in diameter. HS=3
- 129** Elongate, linear, minimally expanding mine characterized by expansions on both ends, one more diffuse than the other; ~ 10-30 mm long; central linear frass tail and distinct lateral reaction rim. HS=3

- 131 Randomly oriented, elongate, spindle- to cigar-shaped striate chitinous cases on top of leaf surface, ranging from 1.5 x 6.0 mm to 0.1 x 1.0 mm, indicating point-source mining; associated with small, circular surface abrasions that are assignable to DT31 or DT29; preserved as a whitish or other glassy surface different than the sediment matrix; large cases have one end as a ragged or setiferous edge. HS=3
- 139 Loosely serpentine mine cutting across secondary venation, with intermittent, intestiniform frass consisting of hardened, particulate pellets arranged into a tightly serpentine trail occupying most of the mine and frequently mineralized dark brown to reddish. HS=2
- 141 Thin, moderately undulatory mine occurring in tissue below sphenopsid stem node; originating circularly around leaf a scar becoming tangential to their lower margin; entirely frass filled. HS=3

Galling

- 11 Galls with a thin, unhardened central area and surrounded by a thick ring of dense, often botryoidal, hardened tissue; variably diametered, circular to polylobate; less than 10 mm in longest dimension. HS=1
- 32 Structurally similar, nondiagnostic, circular to ellipsoidal galls occurring on the interveinal regions of the leaf lamina and not on major veins. HS=2
- 33 Structurally similar, nondiagnostic, circular to ellipsoidal galls occurring on primary veins of the leaf. HS=3
- 34 Structurally similar, nondiagnostic, circular to ellipsoidal galls occurring on secondary veins of the leaf. HS=2
- 49 Flat, circular galls consisting of a large fusanized core greater than 3 mm in diameter and with a distinct, similarly carbonized reaction rim at a distance of one to a few mm. HS=3
- 52 Generally circular, relatively large galls greater than 3 mm in diameter, consisting of woody (fusanized) tissue with radiating partitions. HS=3
- 55 Galls occurring as distinctive swellings of various shapes and sizes on leaf petioles or petiolules. HS=3
- 62 Circular, modestly thickened galls about 5mm in diameter, presenting a pockmarked surface consisting of alternating dark and light patches. HS=3
- 70 Large, compound, heavily thickened galls with a pockmarked surface of miniscule chambers less than 0.5 mm in diameter; whose developmental sequence is characterized initially by thickening of a distal leaf margin, spreading to the entire leaf upon gall maturation, and ending in lobation of the mature gall. HS=3
- 80 Small, hemispherical to rarely more ellipsoidal galls with diameters ranging from ~ 0.1 to 1.0 mm; characterized entirely by featureless, dark, thickened carbonized material and avoidance of primaries and secondaries; can occur in clusters. HS=2
- 83 Circular galls, 4.5 to 8.0 mm in diameter, with a finely particulate, raised fusanized core encompassing 1 to 6 centrally positioned "exit holes" (or possibly larval chambers) less than 0.5 mm in diameter; positioned on blade and typically avoiding veins. HS=3
- 84 Elongate galls situated on a vein, about twice as long as wide, with a thickened margin; distinct elliptical core of fusain is surrounded by a thickened margin; peripheral, small exit holes are present along the gall margin. HS=3
- 85 Sessile, nondistinctive elliptical to lenticular galls with a striate surface centered lengthwise on a midvein or other major vein; possessing a length-to-width ratio of 3.0 to 5.0. HS=3
- 87 Spheroidal to ellipsoidal galls of various surface textures occurring on a twig, short shoot, or other branchlet. HS=3
- 107 A compound and surface-pockmarked gall similar to DT70, consisting of tiny spheroidal to ovoidal chambers ~0.1 to 0.2 mm in diameter, but organized in into discrete nonlobate clusters occupying the central and proximal regions of a pinnule and adjacent frond rachis, occasionally encompassing and causing distortion of adjacent foliar tissue. HS=1

- 110** Ovoidal to circular structures with a central, often darkened, chamber ranging from 8 mm x 5 mm to 1.5 mm x 1.5 mm; surrounded by a sharp boundary of dark, thickened (fusanized) material ranging from 1.0 to 3.0 mm wide; occurring on tertiary veins. HS=3
- 112** Relatively flat, ovoidal to ellipsoidal galls, sometimes with shallow sinuses along margin, and with a distinct outer rim and internally a convoluted surface; often avoiding major veins and sometimes perturbing the course of the veins; some specimens have a more or less concentric pattern of dark linear areas. HS=3
- 115** Ellipsoidal to almost circular galls with longest diameter oriented along parallel-veined leaves, about 2.0 to 5.0 mm long by about 1.5 to 3.0 mm wide; characterized by thickened layer of hardened (woody) tissue peripherally (outer wall) and thinner tissue centrally (inner zone); occurring on a thick epidermal layer floored by parallel veinules; often 5 to 10 galls per pinnule. HS=3
- 116** Columnar galls vertically oriented to and protruding significantly above the leaf surface, and attached to deeper (vascular) tissue; about 1.0 to 1.4 mm in diameter and estimated to be about twice as long; containing a distinct, thin, outer wall and inner contents that are either filled with a radiate cast of matrix sediment or alternatively amber from the host plant, possibly representing postlarval emergence fill; dense occurrences are on some leaves, up to about 15 to 20 galls per leaf. HS=3
- 117** Small, spheroidal (appearing circular) or occasionally ellipsoidal galls on primary (rarely secondary) veins and petiole; typically about 0.5 mm in diameter, but up to 1.1 x 1.5 mm in dimension with long axis parallel to vein; pronounced outer rim; a few examples with several, circular, brownish blotches within the breached gall. HS=3
- 119** Elongate, lobate galls attached by a relatively small base and expanding distally, on secondary veins, ranging from 2 to 3 mm long and 1.2 mm wide at top in largest specimens, often causing deformation of supplying vein; originating from the host-plant secondary vein. HS=3
- 120** Circular to ovate galls, sometimes with a sinuate margin, consisting of a thick, massive, woody outer rim of blocky to radiate fusain; the gall proper typically ranging from 1.5 to 7.0 mm in diameter, characterized by a flat, inner circular region with venation present; attached to a primary or secondary vein; outer wall thickness ranges from 0.25 to 1.0 times the diameter of the inner chamber. HS=2?
- 121** Bud gall with major teratological features, including a bulbous base and beaklike apex; having narrow needle-like structures emerging from distal half of gall; evidently attached basally and sessile to a branchlet. HS=1
- 122** Rounded ellipsoidal galls with smooth surfaces that are gentle swellings oriented parallel to venation of long, narrow leaves; centered on area between major longitudinal veins, often distorting nearby veins; maximum length from 1.0 to 3.0 mm. HS=3
- 123** Inflated, cupped to curled, lobed pinnules with extensive, smooth to undulate surfaces of galled tissue often occupying the entire pinnule, lacking small submillimeter-sized chambers. HS=3
- 125** Rarer circular to more common and larger, variably shaped polylobate galls occurring between major veins; 0.5 to 8.0 mm in longest dimension; appearing flat; of constant thickness and often with a marginal rim. HS=3
- 127** Distinctive ellipsoidal to spheroidal galls with a with a botryoidal to roughened surface; ranging from 3.5 mm to 4.5 mm in length and 1.0 to 2.0 mm in width; extending beyond narrow leaf lamina; apparently supplied by a single vascular trace. HS=3
- 135** Single to conjoined galls, spheroidal to polylobate, from 0.5 mm to 2.0 mm in diameter or longest dimension; on woody axis, frequently in rows along vascular traces. HS=3
- 144** Multiloculate, often fused, externally smooth, small galls; consisting of a circular to ovoidal margin with 2 to 4 central chambers, indicated by a plug of dark (fusanized) central tissue. HS=2?
- 145** Spheroidal, fleshy gall on lamina, approximately 1.0 cm in diameter; with central (collapsed) chamber lined by a thick wall and outer ring of tissue; outer gall formed of thinner tissues. HS=1

- 146 Unilocular hemispherical gall on midrib, approximately 0.8 to 1.0 cm in diameter at base, with a thickened base and a featureless, smooth surface. HS=1
- 147 Small, irregularly-shaped gall, approximately 1 mm in maximum dimension with distinct partitions of tertiary veins separating intervening thickened areas; pustulose surface. HS=1
- 149 Medium to large, elongate, cylindrical to prolonged-ovoidal galls emerging from interveinal region, with a prominent, coarsely ribbed outer surface and a pedunculate base. HS=1
- 150 Elongate galls (aspect ratio > 3:1); with acute terminus, external hardened tissue with transverse structure, and smooth surface; broadly attached and emerging from secondary veins. HS=1

Seed Predation

- 73 Irregularly distributed, often overlapping, larger surface penetrations of the central seed body; each mark greater than 0.5 mm in longest dimension, and consisting of ellipsoidal to lenticular disruptions of seed coat surface that contain disorganized material within. HS=3
- 74 Dispersed smaller surface penetrations or pits of the central seed body; consisting of circular perforations less than 0.5 mm in diameter, and contrasting with adjacent seed coat microstructure. HS=2
- 124 Removal of the entire or major part of the embryonic or nutritive tissues of a three-dimensionally preserved seed, reflected either by amber infill or an evacuated chamber, sometimes with elongate coprolites inside. HS=3
- 140 Removal of megagametophytic, endosperm or adjacent tissues at an attached end of a wind-dispersed seed, characterized by a prominent, ovoidal, furrowed reaction rim surrounding the seed body. HS=1

Fungal

- 58 Unspecified ovoid to polylobate fungal blotches constituting a necrotic area delimited by a diffuse to sharp reaction front. (Currently undifferentiated.) HS=1

Incertae Sedis

- 106 Irregular, epiphyllous patches of elongate to circular roughened areas with a pockmarked texture characterized by a field of circular to elliptical cavities some of which originally were epidermal pustules but are preserved as cavities in negative relief. HS=1?
- 114 Necrotic tissue occurring along the leaf-margin, usually ranging from 1 to 5 mm in thickness, but with a distinct reaction front abutting unaffected foliar tissue; sometimes showing signs of tearing or other abrasion. HS=1