

Fossil arachnids from the earliest Miocene Foulden Maar Fossil-Lagerstätte, New Zealand

PAUL A. SELDEN and UWE KAULFUSS

SELDEN, P.A. & KAULFUSS, U., May 2018. Fossil arachnids from the earliest Miocene Foulden Maar Fossil-Lagerstätte, New Zealand. *Alcheringa* XX, XX–XX. ISSN 0311-5518.

Fossil Arachnida from New Zealand are extremely rare and represented by some unidentifiable amber inclusions only. The first fossil arachnids from New Zealand to be described in detail are presented here, based on four compression fossils from the earliest Miocene Fossil-Lagerstätte at Foulden Maar, South Island. Two specimens are referred to Arachnida *incertae sedis* and Araneomorpha *incertae sedis*, respectively, whereas two specimens are mygalomorph spiders. One of these is placed in the Rastelloidina clade of Mygalomorphae, probably in the Idiopidae, which is represented in New Zealand by the extant *Cantuarina*.

P.A. Selden* [selden@ku.edu] Paleontological Institute and Department of Geology, University of Kansas, Lindley Hall, 1475 Jayhawk Boulevard, Lawrence, KS 66045, USA; U. Kaulfuss [uwe.kaulfuss@otago.ac.nz] Department of Geology, University of Otago, PO Box 56, Dunedin, New Zealand. *Also affiliated with: Natural History Museum, London, UK. Received 12.2.2018; revised 5.3.2018; accepted 6.3.2018.

Key words: Aquitanian, Arachnida, Idiopidae, fossil spiders.

THE NEW ZEALAND spider fauna is well known (Forster 1967, 1968, 1970, 1979, 1988, Forster & Wilton 1973; as reviewed by Vink 2017). Modern systematic studies have been published for several groups (e.g., Vink *et al.* 2013), and an excellent family key and species list is available (Paquin *et al.* 2010), together with a photographic field guide (Vink 2015). In contrast, fossil spiders have been recorded from the country only in the last few years. There are some undescribed spiders and diverse mites reported from Miocene amber of South Island (Kaulfuss *et al.* 2016, Schmidt *et al.* 2018). Preliminary announcements of the specimens described here have been made by Kaulfuss *et al.* (2014, 2015, 2016) and Lee *et al.* (2016). The only other fossil arachnids recorded from New Zealand are some subfossil mites from the Quaternary of the Hutt Valley (Ramsay 1960).

Here, we describe the four arachnid specimens figured by Kaulfuss *et al.* (2015) and Lee *et al.* (2016) from the Foulden Maar Fossil-Lagerstätte, near Middlemarch, northwest of Dunedin, South Island. Two of these (OU45206, OU45209) are rather poorly preserved with pyrite overgrowths, whereas the other two (OU45207, OU45208) show more detail, and lack overgrowth. OU45206 may be a spider or a harvestman. OU45209 is referred to araneomorph spiders. OU45207 and OU45208 are mygalomorph spiders, although little more can be discerned about OU45207 than that.

OU45208 was provisionally identified as Araneidae by Kaulfuss *et al.* (2015). Here, it is referred to the Rastelloidina Raven 1985 clade of the infraorder Mygalomorphae Pocock 1892 on account of the occurrence of a rastellum on the chelicera. It most likely belongs to Idiopidae Simon 1892, represented today in New Zealand by *Cantuarina* Hogg, 1902, which is found mostly on South Island (Marples & Marples 1972).

Geological setting and methods

Geological setting. Foulden Maar is a partly eroded maar-diatreme volcano of the Waipiata Volcanic Field, Otago, New Zealand, with a maar crater filled by lacustrine mass-flow sediments and highly fossiliferous diatomite (Lindqvist & Lee 2009, Kaulfuss 2017). The fossils were collected from a diatomite mining pit (45.5269°S, 170.2191°E) registered as I43/f8503 in the New Zealand Fossil Record Database administered by the Geoscience Society of New Zealand and GNS Science. A $^{40}\text{Ar}/^{39}\text{Ar}$ age of 23.17 ± 0.17 Ma obtained from associated basalt (Lindqvist & Lee 2009) puts the maar-forming eruptions in the latest Oligocene, whereas the upper part of the diatomite sequence where the arachnids were collected is of earliest Miocene (Aquitanian) age based on palynological grounds (Mildenhall *et al.* 2014) and a depositional period of the maar sediments of at least 130 kyrs (Kaulfuss 2017). Diverse palynomorphs and plant macrofossils (leaves, flowers, fruits and seeds) in the sediments are indicative of a Lauraceae-dominated notophyll vine rainforest growing

on volcanic soils around the lake (Mildenhall *et al.* 2014, Lee *et al.* 2016). The arthropod fauna of this forest is represented by compression fossils of diverse insects (Kaulfuss *et al.* 2015, Engel & Kaulfuss 2017) and these four arachnids.

The spiders at Foulden Maar are preserved in part by pyrite replacement (Kaulfuss *et al.* 2015, Lee *et al.* 2016). In some cases, e.g., the mygalomorphs OU45207 and OU45208 described here, this is light, and so the morphology of the specimens is more evident (Figs 1G–H, 2). In the other two specimens, OU45206 and OU45209, pyrite overgrowth has obscured much of

the morphology, so that only the overall shape, but no detail, can be seen (Fig. 1A–F).

Methods. The specimens were prepared under dry conditions using a very fine needle, and photographed with a Canon T3 camera attached to a Nikon SMZ1000 stereomicroscope under ethanol in order to accentuate details. Photographs were manipulated in Affinity Photo (affinity.serif.com). Drawings were made using Autodesk Graphic (graphic.com) from the photographs. Abbreviations: I II III IV, leg numbers; ch, chelicera; cx, coxa; fe, femur; L, length; lb, labium; mt, metatarsus; op, opisthosoma; pa, patella; Pd, pedipalp; ra,

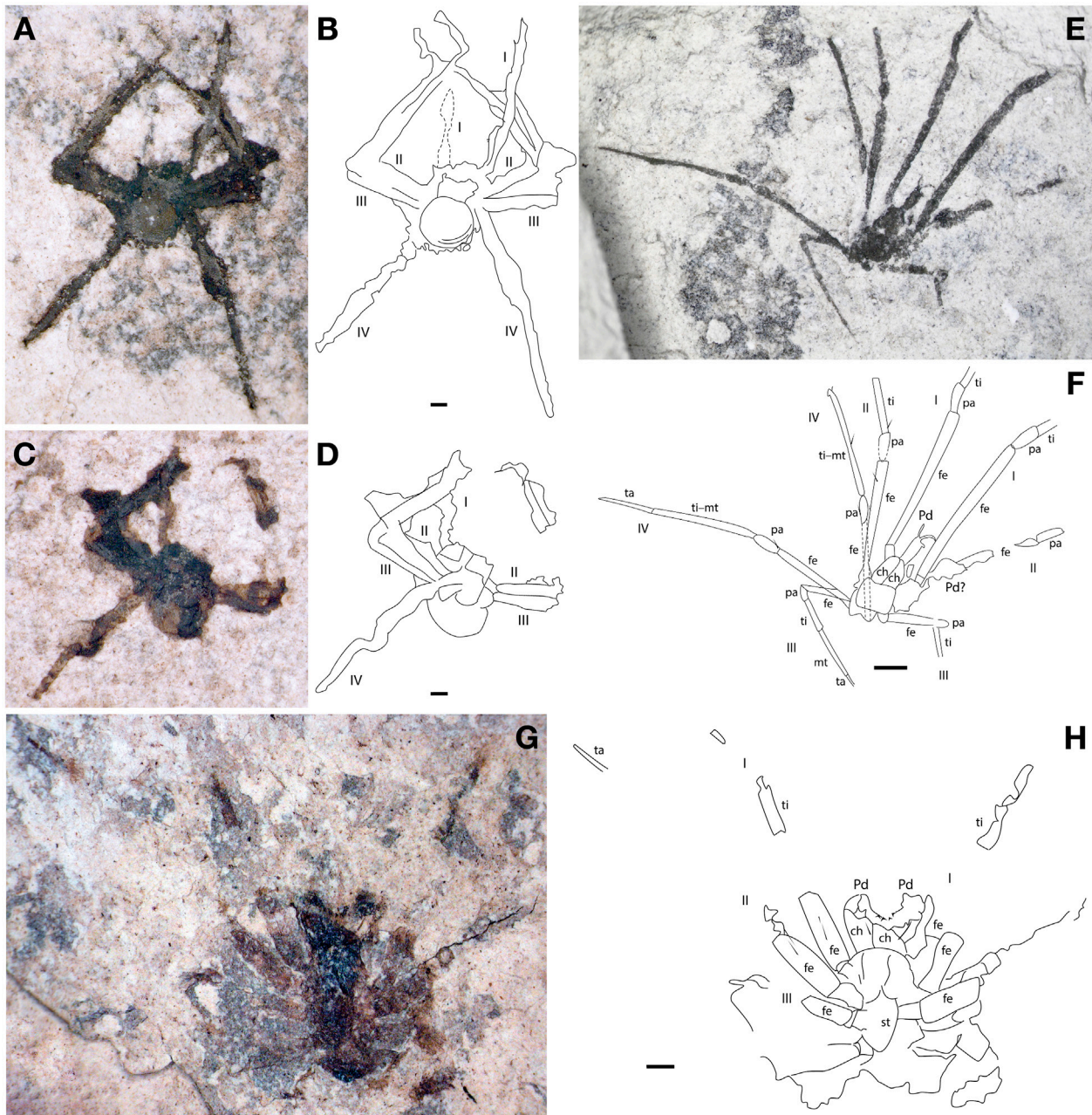


Fig. 1. Arachnids from the earliest Miocene Foulden Maar Fossil-Lagerstätte. A–D, OU45206, *Arachnida incertae sedis*; A, Part; B, Explanatory drawing of A; C, Counterpart; D, Explanatory drawing of C. E–F, OU45209, *Araneomorphae incertae sedis*; E, Photograph; F, Explanatory drawing. G–H, OU45207, *Mygalomorphae incertae sedis*; G, Photograph; H, Explanatory drawing. Scale bars=1 mm.

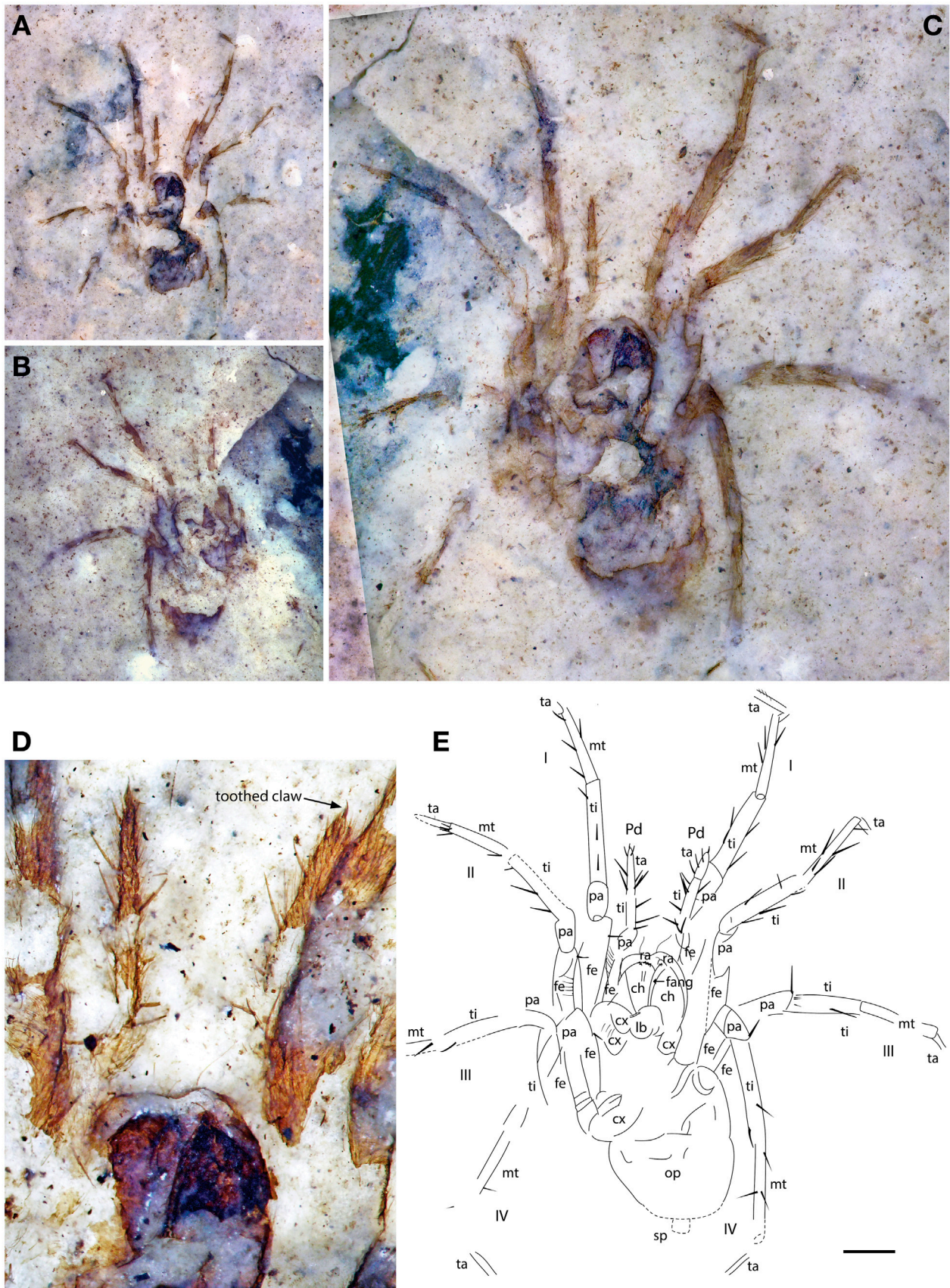


Fig. 2. Spider from the earliest Miocene Foulden Maar Fossil-Lagerstätte. OU45208, *Idiopidae incertae sedis*; **A**, Part; **B**, Counterpart; **C**, Composite photograph of part and counterpart; **D**, Enlargement of **A** showing chelicerae with rastellum teeth and orthognath fang, and pedipalps showing toothed tarsal claw; **E**, Explanatory drawing. Scale bar=1 mm.

rastellum; sp, spinnerets; st, sternum; ta, tarsus; ti, tibia; W, width. All specimens are held in the collections of the Geology Museum (OU), University of Otago, Dunedin, New Zealand.

Systematic palaeontology

Class ARACHNIDA Lamarck 1815

Arachnida incertae sedis (Fig. 1A–D)

Remarks. OU45206 is an arachnid because it has four pairs of legs. Superficially, it resembles either a spider or an opilionid. The body appears to be formed from a single unit, which would suggest Opiliones, but that could be an artefact of compression of a spider with a globular abdomen. Judging from the preserved parts of the legs, they are rather long, which would indicate either an opilionid or an araneomorph spider.

Order ARANEAE Clerck 1757

Suborder OPISTHOTHELAEC Pocock 1892

Infraorder ARANEOMORPHAE Smith 1902

Araneomorphae incertae sedis (Fig. 1E–F)

2015 Kaulfuss *et al.*, Fig. 3B.

Description. Male? Chelicera large, porrect, L 0.92 mm, W 0.40 mm (L/W ratio 2.32). Pedipalp total L *ca* 2.32 mm including distal structures. Legs long, slender; leg III much shorter than others. Macrosetae present on fe, pa, ti. Leg formula 1243. Podomere lengths: Leg I fe 4.66 mm, pa 0.93 mm; Leg II fe 3.19 mm, pa 0.89 mm, ti 1.68 mm; Leg III fe 1.61 mm, pa 0.51 mm, ti 1.01 mm, mt 1.57 mm; Leg IV fe 2.69 mm, pa 0.83 mm, ti–mt 3.30 mm, mt 1.66 mm.

Remarks. OU45209 is referred to Araneomorphae on the basis of its slender, elongate legs, its enlarged, porrect chelicerae, and apparently complex pedipalps. Large, porrect chelicerae suggest the Tetragnathidae Menge 1866, several genera of which are known from New Zealand, as both endemics and introductions (Paquin *et al.* 2010).

Infraorder MYGALOMORPHAE Pocock 1892

Mygalomorphae *incertae sedis* (Fig. 1G–H)

Description. Male? Body and legs highly setose. Sternum scutiform, longer than wide, L *ca* 2.40 mm, W *ca* 1.12 mm. Chelicera large, L \geq 1.62 mm. Pedipalps not slender. Femora I and II with large macrosetae. Podomere lengths: Pd; Leg I fe \geq 2.88 mm; Leg II fe \geq 2.84 mm, ta \geq 1.58 mm, total L fe–ta *ca* 13.00 mm.

Remarks. Specimen OU45207 is placed here on account of its robust form, setose cuticle and stout appendages.

Little detail can be discerned from this poorly preserved spider, but the complex pedipalps suggest an adult male. Clade RASTELLOIDINA Raven 1985

Family IDIOPIDAE Simon 1892

Idiopidae *incertae sedis* (Fig. 2)

2015 Kaulfuss *et al.*, Fig. 3A.

2016 Lee *et al.*, Fig. 5G, H.

Description. Juvenile. Body L 5.48 mm. Opisthosoma L 3.38 mm, W 2.42 mm (L/W ratio 1.40). Chelicera large, L 1.16 mm, W 0.69 mm (L/W ratio 1.66), fang long, L 1.01 mm, gently curved; rastellum of triangular teeth on paturon near base of fang (Fig. 2D–E). Pedipalp slender, with toothed tarsal claw (Fig. 2D). Podomere lengths: Pd pa 0.66 mm, ti 0.71, ta (inc. claw) 0.84 mm; Leg I pa 0.75 mm, ti 1.78 mm, mt 1.60 mm; Leg II pa 0.86 mm, ti 1.66 mm, mt 1.50 mm; Leg III ti 1.47 mm, mt 1.54 mm; Leg IV ti 1.87 mm, mt 2.00 mm.

Remarks. OU45208 is placed here because of its chelicera, which bears a rastellum and a long, paraxial fang. These features occur only in the Rastelloidina. In New Zealand at the present time, Rastelloidina is represented only by *Cantuaria*.

Discussion

Although not very well preserved, OU45208 can be referred to Idiopidae on the basis of its orthognath chelicerae, which bear a rastellum. Idiopids are trapdoor spiders distributed across the southern areas of the world, as far north as Central America, Morocco and India. The subfamily Arbanitinae occurs in Australia and New Zealand, most abundantly in temperate and subtropical habitats south of the Tropic of Capricorn, but multiple lineages have radiated in the mainland Australian arid zone, and one genus, *Cantuaria*, has diversified in New Zealand (Forster 1968, Rix, Raven *et al.* 2017). There are currently 43 accepted species in the genus, all but one of which occur in New Zealand (World Spider Catalog 2018). *Cantuaria mestoni* (Hickman, 1928) occurs in Tasmania, although this species appears to be derived from New Zealand *Cantuaria* (Rix, Raven *et al.* 2017, Rix, Cooper *et al.* 2017). Forster (1968) suggested that, because of the high diversity of *Cantuaria* in New Zealand, the genus might well be split in the future. Victoria Smith has been working on the species relationships of *Cantuaria* and has discovered that the older parts of the phylogenetic tree occur in the southern regions of New Zealand (Victoria Smith, in litt. 2017). According to Rix, Cooper *et al.* (2017), possibly the precursor of the group arrived into southern South Island from Australia, most likely in the earliest Miocene; i.e., at about the same time as our fossil was living in southeastern South Island. Idiopids construct burrows, which may or may not have a trapdoor (Rix, Cooper *et al.* 2017). OU45208 is a juvenile that could

have been dispersing from its burrow in search of a new home when it became immersed in the volcanic lake of Foulden Maar. Alternatively, its burrow may have been washed into the lake, which can occur during heavy rains.

The other arachnid fossils in this collection are less well preserved, and little can be said about them. However, the four specimens are tantalizing evidence of a possibly diverse arachnofauna living in the warm, moist, mesothermal forest surrounding Foulden Maar in the earliest Miocene (Lee *et al.* 2016).

Acknowledgements

We thank the Gibson family and the mining company for kindly allowing access to the site, Vikki Smith and Michael Rix for information about Idiopidae and Daphne Lee for coordinating palaeontological research at Foulden Maar over many years.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

Funding for this study was provided by a Marsden Grant from the Royal Society of New Zealand (11-UOO-043).

References

- CLERCK, C., 1757. *Svenska spindlar, uti sina hufvud-slagter indelte samt under några och sextio särskildte arter beskrefne och med illuminerade figurer uplyste*. L. Salvii, Stockholm, 154 pp., 6 pls.
- ENGEL, M.S. & KAULFUSS, U., 2017. Diverse, primitive termites (Isoptera: Kalotermitidae, *incertae sedis*) from the Miocene of New Zealand. *Austral Entomology* 56, 94–103.
- FORSTER, R.R., 1967. The spiders of New Zealand. Part I. *Otago Museum Bulletin* 1, 1–124.
- FORSTER, R.R., 1968. The spiders of New Zealand. Part II. Ctenizidae, Dipluridae. *Otago Museum Bulletin* 2(1–72), 126–180.
- FORSTER, R.R., 1970. The spiders of New Zealand. Part III. Desidae, Dictynidae, Hahniidae, Amaurobioididae, Nicodamidae. *Otago Museum Bulletin* 3, 1–184.
- FORSTER, R.R., 1979. The spiders of New Zealand. Part V. Cycloctenidae, Gnaphosidae, Clubionidae. *Otago Museum Bulletin* 5, 8–95.
- FORSTER, R.R., 1988. The spiders of New Zealand. Part VI. Cyatholipidae. *Otago Museum Bulletin* 6, 7–34.
- FORSTER, R.R. & WILTON, C.L., 1973. The spiders of New Zealand. Part IV. Agelenidae, Stiphidiidae, Amphinctidae, Amaurobiidae, Neolanidae, Ctenidae, Psechridae. *Otago Museum Bulletin* 4, 1–309.
- HICKMAN, V.V., 1928. Studies in Tasmanian spiders. Part II. *Papers and Proceedings of the Royal Society of Tasmania* 1927, 158–175.
- HOGG, H.R., 1902. On some additions to the Australian spiders of the suborder Mygalomorphae. *Proceedings of the Zoological Society of London* 2, 121–142.
- KAULFUSS, U., 2017. Crater stratigraphy and post-eruptive evolution of the Foulden Maar, southern New Zealand. *New Zealand Journal of Geology and Geophysics* 60, 410–432.
- KAULFUSS, U., HARRIS, A.C., CONRAN, J.G. & LEE, D.E., 2014. An early Miocene ant (subfam. Amblyoponinae) from Foulden Maar: the first fossil Hymenoptera from New Zealand. *Alcheringa* 38, 569–575.
- KAULFUSS, U., LEE, D.E., BARRATT, B.I.P., LESCHEN, R.A.B., LARIVIÈRE, M.-C., DLUSSKY, G.M., HENDERSON, I.M. & HARRIS, A.C., 2015. A diverse fossil terrestrial arthropod fauna from New Zealand: evidence from the early Miocene Foulden Maar fossil lagerstätte. *Lethaia* 48, 299–308.
- KAULFUSS, U., LEE, D.E. & SCHMIDT, A.R., 2016. New discoveries of Miocene arthropods from amber and diatomite deposits in New Zealand. In *Fossils X3, Edinburgh 2016, Abstracts*. PENNEY, D. & ROSS, A.J., eds, National Museums Scotland and Siri Scientific Press, Edinburgh, 26.
- LAMARCK, J.-B., 1815. *Histoire naturelle des animaux sans vertèbres, ... Tome 1*. J. B. Baillière, Paris. xvi + 1–462 pp.
- LEE, D.E., KAULFUSS, U., CONRAN, J.G., BANNISTER, J.M. & LINDQVIST, J.K., 2016. Biodiversity and palaeoecology of Foulden Maar: an early Miocene Konservat-Lagerstätte deposit in southern New Zealand. *Alcheringa* 40, 525–541.
- LINDQVIST, J.K. & LEE, D.E., 2009. High-frequency paleoclimate signals from Foulden Maar, Waipiata Volcanic Field, southern New Zealand: an Early Miocene varved lacustrine diatomite deposit. *Sedimentary Geology* 222, 98–110.
- MARPLES, B.J. & MARPLES, M.J., 1972. Observations on *Cantuarina toddi* and other trapdoor spiders (Aranea: Mygalomorpha) in Central Otago, New Zealand. *Journal of the Royal Society of New Zealand* 2, 179–185.
- MENGE, A., 1866. Preussische Spinnen. Erste Abtheilung. *Schriften der Naturforschenden Gesellschaft in Danzig (N.F.)* 1, 1–152.
- MILDENHALL, D.C., KENNEDY, E.M., LEE, D.E., KAULFUSS, U., BANNISTER, J.M., FOX, B. & CONRAN, J.G., 2014. Palynology of the early Miocene Foulden Maar, Otago, New Zealand: diversity following destruction. *Review of Palaeobotany and Palynology* 204, 27–42.
- PAQUIN, P., VINK, C.J. & DUPÉRRÉ, N., 2010. *Spiders of New Zealand*. Manaaki Whenua Press, Lincoln, vii + 118 pp.
- POCOCK, R.I., 1892. *Liphistius* and its bearing upon the classification of spiders. *Annals and Magazine of Natural History, series* 6(10), 306–314.
- RAMSAY, G.W., 1960. Sub-fossil mites from the Hutt Valley. *Transactions of the Royal Society of New Zealand* 88, 575–576.
- RAVEN, R.J., 1985. The spider infraorder Mygalomorphae (Araneae): cladistics and systematics. *Bulletin of the American Museum of Natural History* 182, 1–180.
- RIX, M.G., RAVEN, R.J., MAIN, B.Y., HARRISON, S.E., AUSTIN, A.D., COOPER, S.J.B. & HARVEY, M.S., 2017a. The Australasian spiny trapdoor spiders of the family Idiopidae (Mygalomorphae: Arbanitinae): a relimitation and revision at the generic level. *Invertebrate Systematics* 31, 566–634.
- RIX, M.G., COOPER, S.J.B., MEUSEMANN, K., KLOPFSTEIN, S., HARRISON, S.E., HARVEY, M.S. & AUSTIN, A.D., 2017. Post-Eocene climate change across continental Australia and the diversification of Australasian spiny trapdoor spiders (Idiopidae: Arbanitinae). *Molecular Phylogenetics and Evolution* 109, 302–320.
- SCHMIDT, A.R., KAULFUSS, U., BANNISTER, J.M., BARANOV, V., BEIMFORDE, C., BLEILE, C., BORKENT, A., BUSCH, A., CONRAN, J.G., ENGEL, M.S., HARVEY, M., KENNEDY, E.M., KERR, P., KETTUNEN, E., KIECKSEE, A.P., LENGELING, F., LINDQVIST, J.K., MARAUN, M., MILDENHALL, D.C., PERRICHOT, V., RIKKINEN, J., SADOWSKI, E.-M., SEYFULLAH, L.J., STEBNER, F., SZWEDO, J., ULBRICH, P. & LEE, D.E., 2018. Amber inclusions from New Zealand. *Gondwana Research* 56, 135–146.
- SIMON, E., 1892. *Histoire naturelle des Araignées*. Volume 1, part 1. Roret, Paris, 1–254.
- SMITH, F.P., 1902. The spiders of Epping Forest. *Essex Naturalist* 12, 181–201.
- VINK, C.J., 2015. *A Photographic Guide to Spiders of New Zealand*. New Holland, Auckland, 1–118.
- VINK, C.J., 2017. A history of araneology in New Zealand. *Journal of the Royal Society of New Zealand* 47, 262–273.
- VINK, C.J., DUPÉRRÉ, N. & MALUMBRES-OLARTE, J., 2013. Periegopidae (Arachnida: Araneae). *Fauna of New Zealand* 70, 1–40.
- World Spider Catalog, 2018. *World spider catalog, version 19.0*. Natural History Museum Bern. <http://wsc.nmbe.ch>