= Kirtlandian =

The Kirtlandian is a North American land @-@ vertebrate faunal age of the Cretaceous period , following the Judithian and succeeded by the Edmontonian . It lasted about 2 million years , ca 74 @.@ 8 to 72 @.@ 8 Mya and is characterized by the ceratopsian Pentaceratops sternbergii , which lived throughout the Kirtlandian . It was first named by R.M. Sullivan and S.G. Lucas in 2003 as a faunal age for the Kirtland and Fruitland formations . Previously , only five land @-@ vertebrate ages were identified from the Late Cretaceous. as identified by Loris S. Russell in 1975 , they include the Paluxian , Aquilan , Judithian , Edmontonian , and the Lancian . Before the naming of the Kirtlandian , three gaps , between the Paluxian and Aquilan , the Aquilan and the Judithian , and the Judithian and Edmontonian , were identified but not named .

The Fruitland Formation measures 97 to 107 metres (318 to 351 ft) thick , and with the 594 metres (1 @,@ 949 ft) of the Kirtland Formation , the Kirtlandian consists of 701 metres (2 @,@ 300 ft) of sediments . The rock types within the formations are primarily coal beds , but also include sandstone , siltstone , mudstone , and shale . Within the sediments with a Kirtlandian age , two local faunas , the Hunter Wash local fauna , and the Willow Wash local fauna , have been identified . The currently accepted date of the Kirtlandian is 74 @.@ 8 to 72 @.@ 8 million years ago .

= = Paleoecology = =

The Kirtlandian is an age of fauna that lasted for 2 million years . It is Campanian in age , and is placed between the Judithian age , which is characterized by older taxa , and the Edmontonian faunal age , characterized by the appearance of Edmontosaurus regalis and Pachyrhinosaurus canadensis . The geological formations found to date or persist from the Kirtlandian are the Bearpaw , the upper Kaiparowits Formation , the Kirtland , Fruitland , Williams Fork , Fort Crittenden , Ringbone , Corral de Enmedio , Packard , and El Gallo formations , and possibly the lower part of the Cerro del Pueblo Formation and upper region of the Aguja Formation . These formations are exposed in Alberta and Montana , Utah , New Mexico , New Mexico , Colorado , Arizona , New Mexico , Sonora , Baja California , Baja California , and possibly Coahuila , and Texas , respectively .

= = = Stratigraphy = = =

The stratigraphy of the Kirtlandian was studied by Robert M. Sullivan and Spencer G. Lucas in 2003 , Sullivan in 2006a , Lucas and Sullivan in 2006b , and Nicholas R. Longrich in 2010 .

= = = = Local faunas = = = =

Two local faunas are known from the Kirtlandian faunal age . They include the Hunter Wash local fauna and the Willow Wash local fauna . The Hunter Wash local fauna was defined as the vertebrates " obtained from the upper 40 feet of the Fruitland Formation and the lower 55 feet of the lower shale of the Kirtland Shale (now a formation) in Hunter Wash (member) . " The Hunter Wash fauna therefore includes all taxa from the Bisti region of the Bisti / De @-@ Na @-@ Zin Wilderness , and the animals from the Fossil Forest and Ah @-@ shi @-@ sle @-@ pah Wash . The Willow Wash fauna was named for all the fauna of the De @-@ na @-@ zin Member of the Kirtland Formation . The majority of the fauna from the Willow Wash were originally thought to belong to the Alamo Wash local fauna of the Ojo Alamo Formation , until it was found that the entire fauna was in fact from the older Kirtland Formation .

= = = = Thickness = = = =

The Kirtland and Fruitland formations both consist of the major formations in the Kirtlandian age . The Fruitland Formation was measured in 2003 to be between 97 and 107 metres (318 and 351 ft)

thick , and the Kirtland was measured at 594 metres (1 @,@ 949 ft) thick . Together they measured 691 to 701 metres (2 @,@ 267 to 2 @,@ 300 ft) . Later in 2010 , a different study found more precise measurements . It found the Fruitland Formation to be 100 metres (330 ft) thick , and the Kirtland Formation to be around 600 metres (2 @,@ 000 ft) thick . These thicknesses combine to give the formation a height of 700 m (2 @,@ 300 ft) .

= = = = Lithology = = = =

The lithology of the Kirtlandian formations are made up of mostly a combination of coal beds . The Fruitland Formation consists entirely of them , and one fifth of all rocks of the Kirtland Formation are a coal . The other common rocks found in the Kirtland Formation are siltstone , mudstone , shale and most commonly , sandstone . The Bisti Bed of the Hunter Wash Member is made up completely of sandstone , which marks the border between the Kirtland and Fruitland formations .

= = = = Age = = = =

The Kirtlandian faunal age was named by Lucas and Sullivan in 2003 , and found by their original study to date from 74 @.@ 9 to 72 million years ago . In 2006 , Sullivan and Lucas refined their estimate , stating that the Kirtlandian ranged from 75 to 72 @.@ 8 million years ago . Later that year , Sullivan changed the time range again , finding that the faunal age lasted only 2 million years , from 74 @.@ 8 to 72 @.@ 8 million years ago . He said that the later part of the Kirtlandian , from the De @-@ na @-@ zin Member of the Kirtland Formation , dated to 73 million years ago , on the basis of ash layers dating to 73 @.@ 04 and 73 @.@ 37 million years ago . This observation was based on findings by Sullivan and Lucas , who dated the two ash layers from 73 @.@ 04 ± 0 @.@ 25 and 73 @.@ 37 ± 0 @.@ 28 million years ago . They also dated the earlier ashes from the Fruitland Formation , which dated to 75 @.@ 56 ± 0 @.@ 41 , 74 @.@ 55 ± 0 @.@ 29 , and 74 @.@ 11 ± 0 @.@ 62 million years ago . The first ash , called by them the Dog Eye Pond , was found slightly higher than the start of the Fruitland Formation , which meant that the start of the Fruitland Formation was older than 75 @.@ 5 million years ago . More precise dating in 2010 by Longrich found that the second youngest ash can actually be dated more precisely than thought by Sullivan (2006) , only having an error range of 0 @.@ 18 million years . Longrich also dated the two older ashes , finding a date the same as that of Sullivan in 2006 . These ash datings are what Sullivan used to find the precise age of the Kirtlandian age .

= = = Fauna = = =

The Kirtlandian has a distinct fauna , including four species distinguishing it from other ages . The species include the dinosaurians Pentaceratops sternbergii , Parasaurolophus cyrtocristatus , and Kritosaurus navajovius , with the only non @-@ dinosaurian being Melvius chauliodous , a fish taxon .

= = = = Fruitland and Kirtland Formations = = = =

The dinosaurian fauna from the Kirtlandian from the Fruitland and Kirtland formations includes the theropods Bistahieversor sealeyi (previously Daspletosaurus and Albertosaurus sp .) , Ornithomimus antiquus , and " Saurornitholestes " robustus (previously Saurornitholestes langstoni) ; the titanosaur Alamosaurus sanjuanensis ; the hadrosaurids Anasazisaurus horneri , Kritosaurus navajovius , Naashoibitosaurus ostromi , Parasaurolophus cyrtocristatus , and Parasaurolophus tubicen ; the ankylosaurians Nodocephalosaurus kirtlandensis , Glyptodontopelta mimus , and Ahshislepelta minor ; and the marginocephalians Sphaerotholus goodwini (called Prenocephale goodwini) , Stegoceras novomexicanum (previously Stegoceras validum) , Pentaceratops sternbergii , Titanoceratops ouranos , and a new genus and species of centrosaurine .

Fossil turtles were very abundant in the Kirtlandian , and in the Campanian in general . Over 200

specimens and 15 species of turtle have been found from the Fruitland / Kirtland Formations . Among the turtles are the bothremydid Chedighaii hutchisoni ; the pleurosternid Compsemys sp . ; the baenodds Denazinemys nodosa and Scabremys ornata (previously Denazinemys ornata) ; the non @-@ baenodd baenids Neurankylus baueri , Thescelus hemispherica , and Thescelus rapiens ; the adocids Adocus bossi and Adocus kirtlandicus ; the nanhsiungchelyids Basilemys gaffneyi and possibly Basilemys nobilis ; the trionychids Aspideretoides austerus , Aspideretoides robustus ; and two indeterminate turtles , one a plastominine , and one assigned to Kinosternoidea .

= = = = Williams Fork Formation = = = =

Kirtlandian fauna are also present in the Williams Fork Formation . The principal index taxon of the Kirtlandian , Pentaceratops sternbergii , in known from the formation , along with the theropods Troodon formosus , Dromaeosaurus albertensis , Saurornitholestes langstoni , Richardoestesia gilmorei , and indeterminate tyrannosaurids ; the ankylosaurians Ankylosaurus magniventris and Nodosauridae indet . ; the ornithopods Thescelosaurus neglectus and an unnamed hadrosaurid . Mammals from the formation include Mesodma thompsoni , Cimolodon nitidus , ? Cimolodon sp . , Cimolomys sp . , cf . Meniscoessus intermedius , Meniscoessus major , Meniscoessus collomensis , ? Paracimexomys sp . , Turgidodon rhaister , Turgidodon russelli , Alphadon marshi , Alphadon wilsoni , Pediomys cooki , Aquiladelphis incus , Eodelphis sp . , and Aenigmadelphys sp. nov . , although many identifications of mammals , as well as dinosaurs are uncertain .

= = = = Fort Crittenden Formation = = = =

The Fort Crittenden Formation is one of many formations dating from inside the Kirtlandian . The formation is characterized by Melvius , a possible index taxon for the Kirtlandian . Species other than Melvius sp. include the fishes Myledaphus bipartitus , cf . Pachyrizodus sp . , lepisosteids , and pycnodontids ; the turtles Brasilemys , " Aspideretes " sp . , and " Plastomenus " , the dinosaurs cf . Saurornitholestes and cf . Richardoestesia ; the amphibians cf . Opisthotriton and cf . Scapherpeton sp . ; the crocodylian Allognathosuchus sp . ; teiid and anguid lizards ; and possibly a pterosaur .

= = = = Ringbone Formation = = = =

Few fossils have been found in the Ringbone Formation , the only significant one being a specimen that is either Albertosaurus sp. or Daspletosaurus sp . , known from a tooth and vertebrae . The only reason the Ringbone Formation is assigned to the Kirtlandian age is because the rocks are the same age as the Fort Crittenden Formation , which contains one of the index taxa of the Kirtlandian .

= = = = Upper Aguja Formation = = = =

The upper region of the Aguja Formation is from the Kirtlandian . Fauna from the section of this formation include the protostegid turtles Terlingualchelys fischbecki and " Aspideretes " ; the crocodylian Deinosuchus riograndensis (previously Phobosuchus) ; the dinosaurs Agujaceratops mariscalensis , Kritosaurus navajovius , Kritosaurus sp . , Panoplosaurus sp . , ? Stegoceras sp . , Saurornitholestes langstoni , Richardoestesia isosceles , Richardoestesia cf. gilmorei , an intermediate tyrannosaurid , and an unnamed ornithomimid .

= = = Paleobiogeography = = =

The two main formations of the Kirtlandian , the Fruitland and Kirtland , were originally included in the older Judithian age , an interpretation superseded with the naming of the Kirtlandian . In 1975 , Russell identified five Late Cretaceous land @-@ vertebrate ages , the Paluxian , Aquilan , Judithian , Edmontonian , and Lancian , based on mammal assemblages . Three previously unnamed faunal

ages were given names and term " Kirtlandian " was chosen for the gap between the Judithian and Edmontonian . Pentaceratops is distributed throughout all of the San Juan Basin . Outside of the basin , Pentaceratops is well @-@ known , and known with certainty , from the Williams Fork Formation . This means that the formation , along with the Cretaceous formations of the basin , are inside the Kirtlandian .

= = = = Associations = = = =

The Kirtlandian is characterized by a single vertebrate association . The association was identified by Lehman in 2001 and termed the " Kritosaurus - Parasaurolophus association " . This association was found to only be present in the later half of the Kirtlandian faunal age , around 73 @.@ 4 ? 73 million years ago . Another association , this one the " Corythosaurus - Centrosaurus association " is found at the very end of the Judithian , right before the Kirtlandian , between 76 @.@ 5 and 74 @.@ 2 million years ago . Another association , the " Pachyrhinosaurus - Edmontosaurus association " , was found to date to 70 @.@ 6 mya , and it used to symbolize the end of the Kirtlandian .