

Cellular-level preservation of cutaneous spikes in an Early Cretaceous iguanodontian dinosaur

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1. Extended osteological description:

Skull

With an elongated preorbital region that accounts for about 61 % of the total skull length, the general proportions of the skull are similar to those of *Bolong*¹², *Jinzhousaurus*^{S1}, *Bayannurosaurus*^{S2}, *Iguanodon*^{S3}, and *Mantellisaurus*⁶.

External naris —The external naris is dorsoventrally narrow and proportionally shorter (26 % of preorbital length) than in *Bolong* (45 %) ¹², *Jinzhousaurus* (38 %) ^{S1}, *Altirhinus* (approximately 56 %) ^{S4} and Hadrosauridae. It more closely resembles the condition in *Iguanodon*^{S3}, *Mantellisaurus* (approximately 28-30%)^{S5}, and *Ouranosaurus* (approximately 18%)^{S6}. Because of its short size, the caudal portion of the external naris does not significantly extend over the rostral part of the maxillary tooth row, unlike all but the most earliest-branching (e.g., *Dryosaurus*)^{S1, S7}.

Nasal — The left nasal is visible in lateral view (Fig. 1A-B). Similarly to derived non-hadrosaurid Iguanodontia, it is an elongated strap-like elements, slightly arched in lateral view. It lacks the inflation and curvature that characterize *Altirhinus*^{S4} and *Brighstoneus*^{S8}, and the paired domes present in *Ouranosaurus*^{S6}. It divides rostrally into an elongated rostromedial process, which participates in half of the dorsal margin of the external naris, and a shorter sub-triangular rostrolateral process, which forms the caudal fifth of the ventral margin of the external naris. The caudal corner of the external naris is therefore entirely circumscribed by the nasal, as also observed in *Bolong*¹², *Jinzhousaurus*^{S1}, *Brighstoneus*^{S8}, *Ouranosaurus*^{S6} and most hadrosaurines (e.g., *Gryposaurus*, *Edmontosaurus*, and *Brachylophosaurus*). The rostrolateral process of the nasal is absent in *Iguanodon*^{S3}, *Mantellisaurus*⁶, *Equijubus*^{S9} and *Altirhinus*^{S4}. Caudally, the ventral margin of the nasal has an extended contact with the dorsal process of the maxilla, then with the lacrimal. A nasal/lacrimal contact can be observed in *Ouranosaurus*^{S6}, *Altirhinus*^{S4}, and maybe *Mantellisaurus*⁶; there is no contact between the nasal and the lacrimal in *Jinzhousaurus*^{S1}, *Bolong*¹², *Iguanodon*^{S3}, and *Equijubus*^{S9}.

Premaxilla — The left premaxilla is exposed in lateral view, but the lateral expansion of its rostral half is clearly eroded; the right one is disarticulated, so the medioventral aspect of its rostral portion is exposed (Fig. 1A-B). The rostral part of the oral margin is thickened and very rugose, indicating that it was covered by a keratinous ramphotheca in life^{S10}. The oral margin of the premaxilla is deflected lateroventrally, although it appears less strongly downturned and it does not extend ventrally from the dentary tooth row as far as in *Jinzhousaurus*^{S1}, *Altirhinus*^{S4}, *Bayannurosaurus*^{S2}, *Equijubus*^{S9}, and

Protohadros^{S11}. The degree of transverse flaring of the rostral part of the nasal remains modest, in degree to what can be observed in *Iguanodon*^{S3}, *Mantellisaurus*⁶, *Jinzhousaurus*^{S1}, *Equijubus*^{S9}, and *Probactrosaurus*^{S12}). The nasal process is mediolaterally compressed and gently curved, participating in the rostradorsal margin of the external naris. Its caudolateral side has an elongated articular surface covered by the rostromedial process of the nasal. The nasal process forms a narrow internarial septum that separates the paired nasals and leads caudally into the narial chamber. This internarial septum is significantly longer than in other non-hadrosaurid Hadrosauroidea, being nearly as long as the external naris itself. A foramen is positioned close to the rostral margin of the internarial septum. The caudolateral process is straight and dorsoventrally tall. Its distal portion is broken off, so its precise caudal extension cannot be ascertained. It did not extend towards the lacrimal, unlike in most non-hadrosaurid styracosternans. Rostrally, the caudolateral process is separated from the narial fossa by a blunt oblique ridge, as also observed in *Bolong*¹².

Maxilla — The left maxilla is visible in lateral view (Fig. 1A-B). It is triangular in lateral view but, compared to other non-hadrosaurid Hadrosauroidea, it is proportionally high, about two times as long as high, only. The maxillary dental battery is composed of 10-11 tooth rows. Unlike in *Jinzhousaurus*^{S1}, *Altirhinus*^{S4}, *Equijubus*^{S9}, *Shuangmiaosaurus*^{S13} and *Protohadros*^{S11}, the rostral tip of the maxilla is not distinctly down-turned. The apex of the dorsal process lies approximately at the mid-point of the bone, as also observed in the basal hadrosauroid *Gilmoreosaurus*^{S14}; the apex of the maxilla is usually caudal to the centre of the bone, as observed in e.g. *Jinzhousaurus*^{S1}, *Bolong*¹², *Bayannurosaurus*^{S2}, *Iguanodon*^{S3}, *Mantellisaurus*⁶, *Brighstoneus*^{S8}, *Proa*^{S15}, *Ouranosaurus*^{S6}, and most derived hadrosauroids. The apex of the dorsal process is slightly truncated by a reduced articular facet for the lacrimal, whereas its caudal border is notched by the ventral margin of the antorbital fenestra. Because of the presence of a small fault in the fossiliferous slab, the caudal portion of the skull has been slightly rotated clockwise, in relation to the maxilla. For this reason, the size of the antorbital fenestra is presumably exaggerated. This fenestra is open in *Bayannurosaurus*^{S2}, *Iguanodon*^{S3}, *Mantellisaurus*⁶, *Brighstoneus*^{S8}, *Proa*^{S15}, and *Ouranosaurus*^{S6}, whereas it is absent in *Jinzhousaurus*^{S1}, *Bolong*¹², and more derived hadrosauroids. Caudal to the antorbital fenestra, the caudal border of the dorsal process of the maxilla forms the ventral margin of a smaller additional antorbital foramen, which potentially corresponds to the depression at the junction between the lacrimal and the maxilla, in *Bolong*¹². The lateral side of the maxilla is gently convex dorsoventrally, contrasting with the situation observed in *Jinzhousaurus*^{S1} and *Equijubus*^{S9}, in which a well-developed, acute and rostrocaudal ridge defines the dorsal boundary of a deep buccal emargination. As also observed in *Bolong*¹², the slight buccal emargination is limited dorsally by a series of elliptical foramina. The jugal process appears rather

prominent and hook-like, as also observed in *Jinzhousaurus*^{S1}, *Iguanodon*^{S3}, *Mantellisaurus*⁶, *Ouranosaurus*^{S6}, *Altirhinus*^{S4}, *Probactrosaurus*^{S12} and *Bactrosaurus*^{S16}, contrasting with the poorly developed process in *Equijubus*^{S9} and *Fukuisaurus*^{S17}.

Lacrima — The lacrimal is a subtriangular bone that participates in the rostral margin of the orbit and the dorsal margin of the antorbital fenestra (Fig. 1A-B). Its rostral corner is damaged at the level of the fault in the skull slab; it was however not extensively elongated as in *Equijubus*^{S9}. Its straight caudal border is thicker than the rostral one and participates in the rostral margin of the orbit. Its dorsocaudal corner is covered by the prefrontal. Its ventral border is concave, where it forms the dorsal margin of the additional antorbital foramen, together with the maxilla. Above this opening, the lateral body of the lacrimal is pierced by two smaller foramina; a single foramen was described at this level both in *Jinzhousaurus*^{S1} and *Bolong*¹². As in *Ouranosaurus*^{S6}, but unlike in *Iguanodon*^{S3}, *Mantellisaurus*^{S5}, *Jinzhousaurus*^{S1} and *Bolong*¹², the lacrimal contacts the nasal.

Jugal — Although it is proportionally longer and dorsoventrally narrower, the maxillary process of AGM 16793 closely resembles that of *Jinzhousaurus*^{S1} (Fig. 1A-B). Rostrally, a small triangular projection from the maxillary process is intercalated between the maxilla and the lacrimal, as also described in *Bolong*¹²; however, this rostral projection is less developed than in *Altirhinus*^{S4}. The dorsal side of the rostral spur is concave, forming a limited articular facet for the lacrimal. Caudal to the lacrimal facet, the dorsal side of the maxillary process is straight, forming the ventral margin of the orbit. The ventral side of the maxillary process is sinuous and fits the jugal process of the maxilla. This morphology of the maxillary process differs from the condition in *Equijubus*, in which the maxillary process is exceptionally elongated, with a peg-like rostral projection^{S9}. The postorbital process has about the same length as the maxillary process, although it is significantly longer in *Jinzhousaurus*^{S1}. These processes form together an angle of about 100°. The postorbital process is rostrocaudally narrow and tapers dorsally and its rostral margin articulates with the postorbital. The quadratojugal process is partly destroyed, but it apparently extended almost parallel to the postorbital, limiting a narrow infratemporal fenestra. The ventral flange of the jugal is angular and extends further ventrally than in *Jinzhousaurus*^{S1}, *Mantellisaurus*^{S5}, *Iguanodon*^{S3}, and *Brighstoneus*^{S8}.

Quadratojugal — The respective limits between the quadrate and the quadratojugal are difficult to distinguish. The quadratojugal seems to be a relatively narrow and flat bone sandwiched between the jugal and the quadrate (Fig. 1A-B).

Prefrontal — The caudal border of the prefrontal articulates with the postorbital, excluding the frontal from the orbital margin. In lateral view, the prefrontal has an almost straight outline, where it forms the rostradorsal margin of the orbit (Fig. 1A-B). As the orbital margins of the lacrimal and the jugal are also straight, the orbit of AGM 16793 consequently looks angular, contrasting with the more rounded condition observed in *Mantellisaurus*⁵⁵ and *Iguanodon*⁵³. However, it cannot be excluded that this shape was influenced by slight postmortem distortion.

Postorbital — In lateral view, the postorbital is a subtriangular bone with proportionally short jugal and squamosal processes (Fig. 1A-B). This morphology is a byproduct of the noteworthy rostrocaudal and dorsoventral expansion of the main body of the bone. It resembles the condition encountered in the latest Cretaceous saurolophine *Edmontosaurus*⁵¹⁸. The central plate of the postorbital is less enlarged in other non-hadrosaurid iguanodontians and the jugal and squamosal processes are consequently longer.

Squamosal — The left squamosal is preserved but is too crushed to be adequately described. The postorbital process appears relatively short and extensively covered by the squamosal process of the postorbital. Both the pre- and postcotyloid processes appear short, although it is likely attributable to their poor preservation state (Fig. 1A-B).

Quadrate — Both quadrates are partly visible (Fig. 1A-B; Fig. S1). They appear proportionally elongated dorsoventrally and narrow rostrocaudally in lateral view, as also observed in *Bolong*¹². The caudal margin of the quadrate is slightly concave, so that this bone looks slightly deflected caudally, as observed in numerous hadrosauriforms including *Jinzhousaurus*⁵¹. In lateral view, there is a prominent notch in the rostral margin of the quadratojugal wing that marks the position of the paraquadratic foramen. Dorsal to this notch, the rostral margin of the quadrate is considerably expanded rostrally to form a prominent quadratojugal wing, which bears a deep groove with sharp and acute margins. The pterygoid wing extends medially and slightly rostrally. The distal end of the quadrate forms a large hemispherical lateral condyle and a smaller medial condyle.

Pterygoid — The right pterygoid is partly visible in AGM 16793 (Fig. 1A-B; Fig. S1). The quadrate ramus completely covers the caudal side of the pterygoid wing of the quadrate and partly the caudal aspect of the quadrate shaft. The thicker ventral margin of the quadrate ramus extends rostradorsally towards the central plate of the bone and is part of the main buttressing pterygoid flange. The ectopterygoid ramus is a short rostroventral projection from the central plate of the pterygoid.

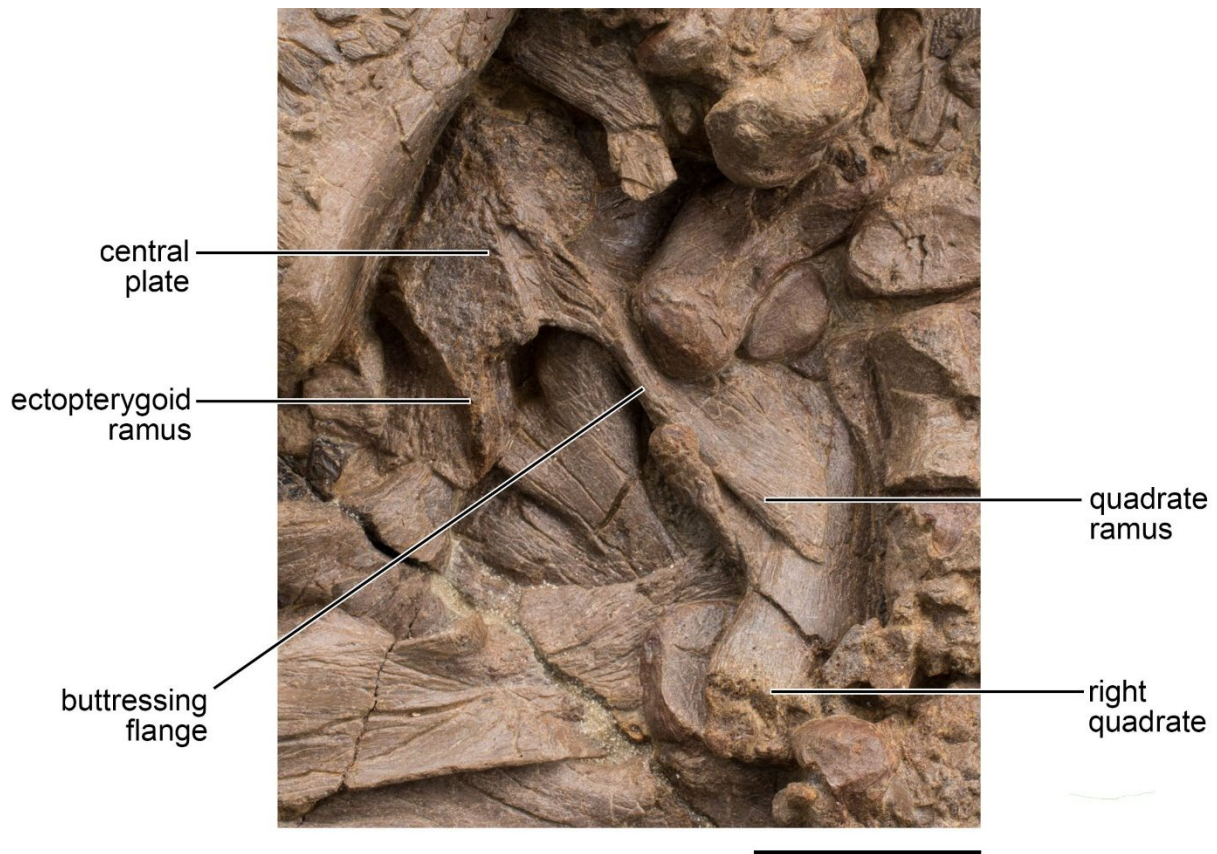


Figure S1 – Close-up of the caudal portion of the skull of *Haolong dongi* AGM 16793.
Scale bar = 2 cm.

Basioccipital — The basioccipital is displaced caudally and slightly ventrally (Fig. 1A-B; Fig. S2). It is not fused to the exoccipitals. The occipital condyle has a subelliptical outline in caudal view; its articular surface is not perfectly vertical as in hadrosauroids, but oriented caudoventrally, as observed in the basal Hadrosauriformes, including *Iguanodon*^{S3}, *Mantellisaurus*^{S5}, *Ouranosaurus*^{S6}, and *Bolong*¹². Rostral to the condyle, the basioccipital is constricted both dorsoventrally and mediolaterally to form the short condylar neck ; a thin sagittal crest extends along its ventral surface. The basioccipital expands again rostrally to participate in the caudal part of the paired sphenoccipital tubercles. At this level, the basioccipital is fused to the basisphenoid; however, the latter element is too fragmentary to be adequately described in this specimen. At the ventral limit of the suture between the basioccipital and the basisphenoid, a deep fossa, formed by both adjacent bones, may mark the attachment site of *M. rectus capitis rostralis*^{S16}.



Figure S2 – Basioccipital of *Haolong dongi* AGM 16793. Scale bar = 2 cm.

Exoccipital — Because the specimen was compressed during fossilization, both exoccipitals are broken off and displaced (Fig. 1A-B; Fig. S3). Only a limited amount of information is therefore available. The exoccipital condyloids appears rather slender. On the caudal aspects of the condyloids, two large foramina probably represent the passages for the hypoglossal nerve rostrally (XII) and the accessory nerve (XI) caudally. The mediolaterally wide paroccipital processes have a pendant aspect and projects ventrolaterally.

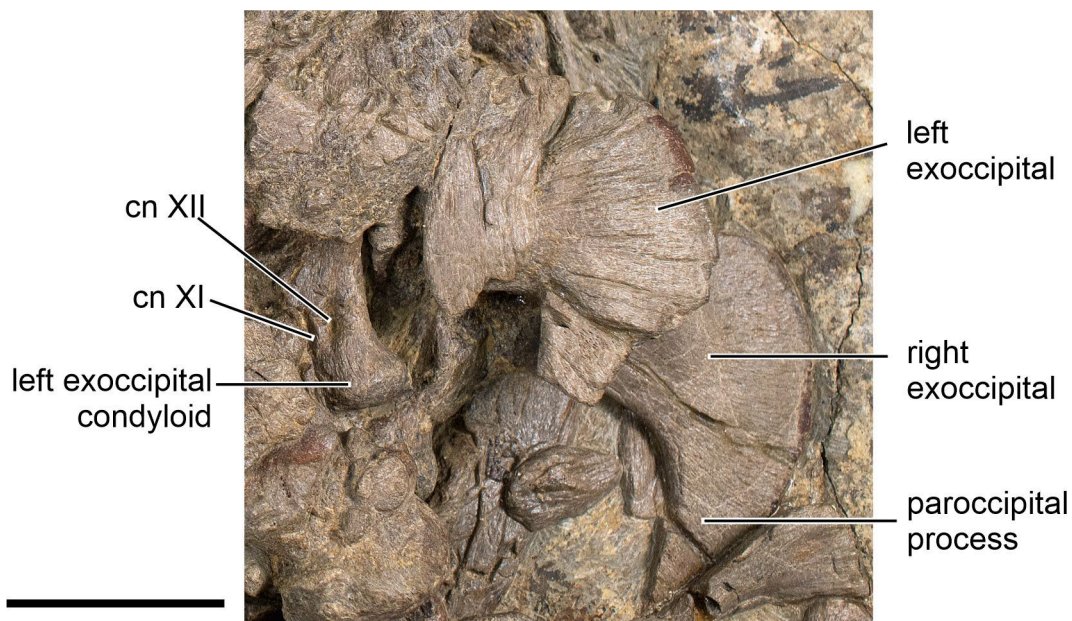


Figure S3 – Left and right exoccipitals of *Haolong dongi* AGM 16793. Scale bar = 2 cm.

Stapes - The right stapes is preserved along the medial side of the upper half of the right quadrate (Fig. S4). Its shaft is 2.5 cm long and particularly delicate, about 0.8 mm thick, and slightly curved. Its proximal end expands into a 4.5 mm -wide footplate. This stapes is associated with a patch of darker and granular structure, tentatively interpreted as a fragment of tympanic membrane.

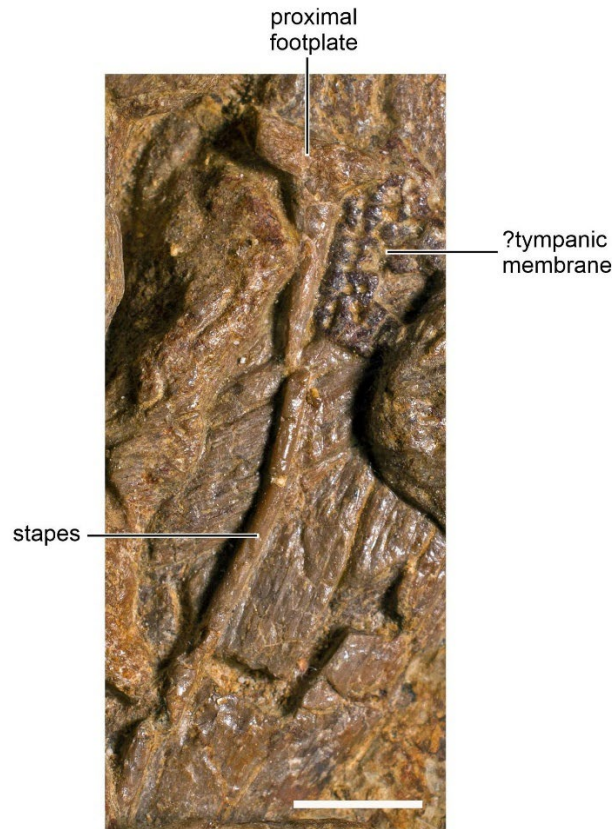


Figure S4 – Stapes of *Haolong dongi* AGM 16793. Scale bar = 4 cm.

Mandible

Predentary — The predentary is visible in left lateral view (Fig. 1A-B; Fig. S5). Its ventral portion is poorly preserved, hampering its description. Its U-shaped oral border bears five pairs of conical projections, which are better developed than in *Jinzhouosaurus* and decrease in size caudally. Beneath the denticulate border, the predentary is punctured by foramina and grooves associated with the attachment of a keratinous beak. The ventral surface of the predentary is gently convex in lateral view, fitting into the rostradorsal articular surface of the dentary. Although it is completely eroded, the ventral process appears particularly massive.

Dentary — The left dentary is visible in lateral view (Fig. 1 A-B). Its general proportions are similar to those in *Jinzhouosaurus*^{S1} and *Bolong*¹², more robustly built than the elongated dentaries of *Brighstoneus*^{S8}, but more slender than the exceptionally deep dentary of *Fukuisaurus*^{S17}. In lateral view, its ventral and dorsal borders are subparallel. The rostral end of the dentary is not significantly downturned, differing from the strongly deflected dentary symphysis described in *Altirhinus*^{S4} and *Protohadros*^{S11}. Similar to other hadrosauriformes, the articular surface for the predentary extends through the entire height of the rostral margin of the dentary. In lateral view, the rostral end of the dentary is scoop-shaped, and its rostral tip is located at or close to the ventral margin. It contrasts with the situation in *Bolong*, in which the rostradorsal articular surface for the predentary occupies less than two-thirds of the height of the dentary in lateral view, therefore placing the rostral tip above the ventral third of the dentary¹². The buccal emargination separating the tooth row from the lateral aspect of the bone looks less developed than in *Bolong* and *Jinzhouosaurus*, but it may be the results of important postmortem deformation. Caudodorsally, the coronoid process is inclined slightly caudally to the long axis of the dentary as observed in *Bolong* and other non-hadrosauroid iguanodontians¹². In *Jinzhouosaurus*, the coronoid process forms a 90° angle with the long axis of the bone^{S1}. Although it is partly obscured, the apex of the coronoid process does not seem rostrocaudally expanded. At least 13 tooth positions are present. The diastema between the first tooth position and the articular surface for the predentary is not larger than two crown widths.

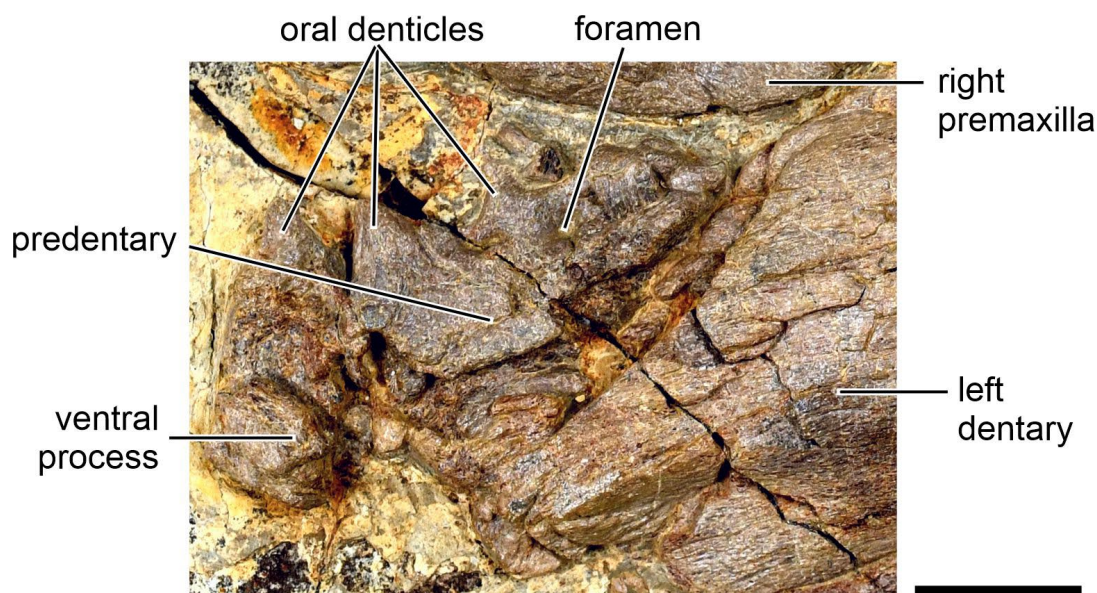


Figure S5 – Rostral region of the lower jaw of *Haolong dongi* AGM 16793. Scale bar = 2 cm.

Surangular — The left surangular is exposed in medial view ventrally to the skull, after pivoting 180° from its initial position (Fig. 1A-B; Fig. S6). Rostrally, it forms a high, broad, and triangular dorsal process that formed the caudal part of the coronoid process. The contribution of the surangular to the coronoid process is more substantial than in *Jinzhousaurus* and more derived hadrosauroids^{S1}, resembling the condition in *Iguanodon*^{S3}, *Mantellisaurus*^{S5}, and *Ouranosaurus*^{S6}. The rostral margin of the dorsal process is sigmoidal and, at mid-height, it forms a small embayment, as also observed in *Jinzhousaurus*, *Altirhinus* and *Lanzhousaurus*^{S1}; this embayment corresponds to the ‘large foramen’ described in *Hypsilophodon*^{S4, S19}. At about the same height, a second foramen pierces the lateral wall of the dorsal process of the surangular. This foramen is present in the body of the surangular in e.g. *Hypsilophodon*, *Camptosaurus*, *Iguanodon*, *Mantellisaurus*, *Ouranosaurus*, *Altirhinus*, *Equijubus*, *Eolambia*, *Protohadros*, and *Jinzhousaurus*^{S20}, although it is usually located lower on the surangular, near the mandibular glenoid. In contrast, hadrosaurids, and some derived non-hadrosaurid hadrosauroids – such as *Bactrosaurus*^{S16}, *Telmatosaurus*^{S21}, and *Tethyshadros*^{S22} – lack this surangular foramen. The caudal margin of the dorsal process descends less abruptly than in *Jinzhousaurus*^{S1} and *Altirhinus*^{S4}. The retroarticular process is prominent, lobate, and upturned above the glenoid. It is mediolaterally compressed, with a thin ventral edge. Beneath the glenoid, the medial side of the surangular forms an elongated groove for insertion of *M. pterygoideus dorsalis*. This facet extends caudally towards the inner side of the retroarticular facet.

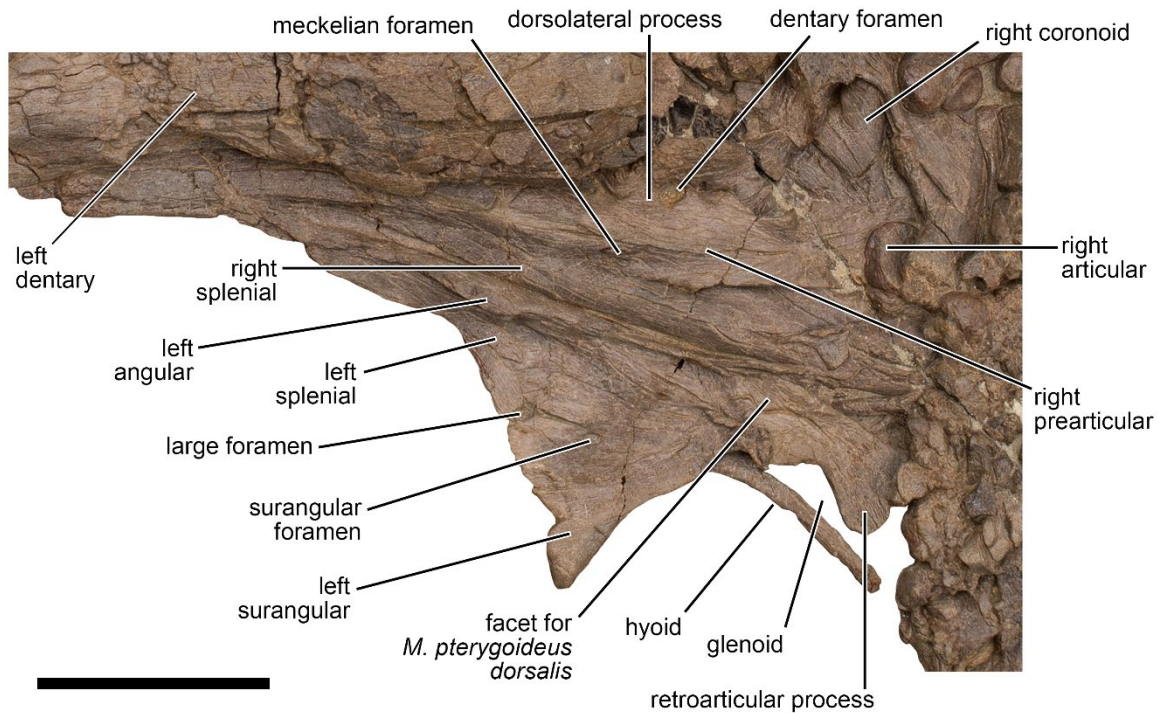


Figure S6 – Ventrolateral region of the lower jaw of *Haolong dongi* AGM 16793. Scale bar = 5 cm.

Angular — The left angular is preserved in articulation with the surangular and is visible in medial view. The bone is long and thin, with a sinuous dorsal edge (Fig. 1A-B, Fig. S6). Its caudal half tapers caudally and articulates with the lower edge of the surangular along a sinuous line. Rostral to the surangular articulation, the angular is deeply excavated to form a dorsoventrally wide groove that was extensively overlapped by the dentary. The rostral end of the angular tapers again to fit underneath the ventral edge of the dentary.

Splenial — The splenial is a thin, elongate, and triangular bone that lies against the caudomedial aspect of the dentary, below the prearticular (Fig. 1A-B, Fig. S6). Caudally to its apex, a deep notch forms the rostral part of the Meckelian fenestra, as also described in *Altirhinus*^{S4}.

Preatricular — The prearticular spans much of the area of the dentary beneath the dental magazine, forms the medial wall of the adductor fossa, and clamps the medial side of the articular (Fig. 1A-B, Fig. S6). Its rostral process is appressed to the medial wall of the dentary and covers Meckel's canal. Caudally, its dorsal margin sweeps smoothly dorsally toward the coronoid process of the dentary. At approximately mid-length along its dorsal margin a short as in *Thescelosaurus*^{S23} and limits a small dorsal foramen. Beneath the coronoid process, the dorsal edge of the prearticular descends gradually,

forming the medial wall of the adductor fossa. As also described in *Altirhinus*^{S4}, the prearticular ends at a small raised area, which marks where the prearticular appears to have met the articular at the rostral edge of the quadrate cotylus.

Articular — The articular is small and lozenge-shaped, lying between the surangular and the prearticular (Fig. S6). It forms the medial portion of the articular surface of the glenoid and the medial part of the retroarticular process.

Coronoid — The right coronoid is preserved as a small elliptical bone that lies on the medial side of the coronoid process of the dentary (Fig. S6).

Teeth — The teeth of AGM 16793 resemble those of *Bolong*¹², *Jinzhousaurus*^{S1}, *Iguanodon*^{S3} and *Mantellisaurus*^{S5}. There are 10 or 11 tooth position on both the maxilla and the dentary and only one functional tooth for each tooth position (Fig. S7). As in *Bolong*, the mesial teeth are the smallest in both the maxillary and dentary tooth rows.

The maxillary teeth are slightly narrower than the dentary teeth. Their mesial and distal edges are roughly parallel, so that they look quadrangular in lateral view. Although the proportions of the crown are variable within the dental battery, the height / width ratio of the crown is lower than 2. An extensive dorsolaterally-inclined wear facet truncates their lingual side. The labial side of the crown is thickly enameled, and the margins of the unworn partially erupted teeth are strongly denticulate. A prominent primary ridge extends along the enameled labial side of the crown. It is placed distally, as in *Iguanodon*^{S3}, *Mantellisaurus*⁶, and *Jinzhousaurus*^{S1}. In *Bolong*, the primary ridge is displaced more distally and, unlike in AGM 16793, it is deflected distally on all the maxillary teeth¹². Up to 5 secondary ridges are positioned mesial to the primary ridge and up to 3 distal to the primary ridge; all extend to the apex of the crown. The lingual sides of the dentary teeth are not observable in this specimen.



Figure S7 – Lateral view of the maxillary and dentary teeth of *Haolong dongi* AGM 16793 under normal light (A) and LSF (B). Scale bar = 2 cm.

Axial skeleton

There are 11 cervical vertebrae as in *Iguanodon*, *Mantellisaurus*, *Ouranosaurus*, and probably *Bolong*.

Atlas – In AGM 16793, the atlas complex is represented by disarticulated intercentrum, odontoid process and right neural arch (Fig. 2, Extended Data Fig. 9). The intercentrum is a transversely wide and craniocaudally short subcrescentic element visible in dorsal view. Its dorsal surface is excavated to receive the ventral surface of the odontoid. On each side of this depression, rugose shoulders mark the

articulation with the neural arches. The craniodorsal surface of the intercentrum forms a shallow, concave, and craniodorsally-directed surface for articulation with the occipital condyle.

The odontoid is not fused with the axial centrum and is visible in dorsal view. It is hemispherical in outline and proportionally much shorter craniocaudally than e.g. in *Mantellisaurus*^{S5}. Its cranial surface is convex for articulation with the occipital condyle, whereas its dorsal surface is perfectly flat.

The right neural arch is visible in medial view. Its ventral end forms a mediolaterally widened and convex pedicel for articulation with the intercentrum. Above the pedicel, the medial wall of the neural arch becomes deeply concave, forming the lateral margin of the neural canal. The dorsal portion of the neural arch expands and curves medially and caudally.

Axis – The axial intercentrum is visible in ventral view, in connection with the atlantal intercentrum (Fig. 1A; Fig. S8). It is a sub-elliptical element: its caudal margin articulates with the axial intercentrum and is transversely wider, but less convex than its cranial border. Its ventral surface is shallowly concave.

The axial centrum is constricted both dorsoventrally and transversely at about mid-length. Its ventral surface is transversely flattened and not keeled. Similar to other Hadrosauriformes, the neural arch is well developed, forming a large, craniocaudally expanded, neural spine. The short transverse process is located on the lower half of the lateral side of the neural arch and it forms a square diapophysis. Cranially at the base of the neural spine, elongated prezygapophyseal processes project cranially, as also observed in *Bolong*¹². Caudally, the neural spine bifurcates into two large postzygapophyseal processes that considerably overhang the cranial part of the third cervical vertebra. These processes support the large elliptical postzygapophyses that face ventrally and slightly laterally.

Postaxial cervical vertebrae – The centrum of the 3rd cervical vertebra is opisthocoelous, with a hemispherical cranial articular surface and a concave caudal surface (Fig. 1A; Fig. S8). It appears proportionally shorter than in *Bolong*¹². Its ventral surface forms a low, thick and rugose keel. The large parapophysis is located on the lateral side of the centrum, close to its cranial border. The neural arch is robust. The strong, pillar-like, prezygapophyseal process extends craniodorsally and supports the large prezygapophysis at its rostradorsal end; its lateral end supports the small transverse process and diapophysis for articulation with the cervical rib heads. The postzygapophyseal process is long and stout, diverging caudally and laterally to cover the prezygapophyseal process of the fourth cervical vertebra.

The other cervical vertebrae are too poorly preserved to be adequately described. The ventral keel is well developed passing along the cervical series (Fig. S8). The neural spines of the cervical vertebrae are not visible.

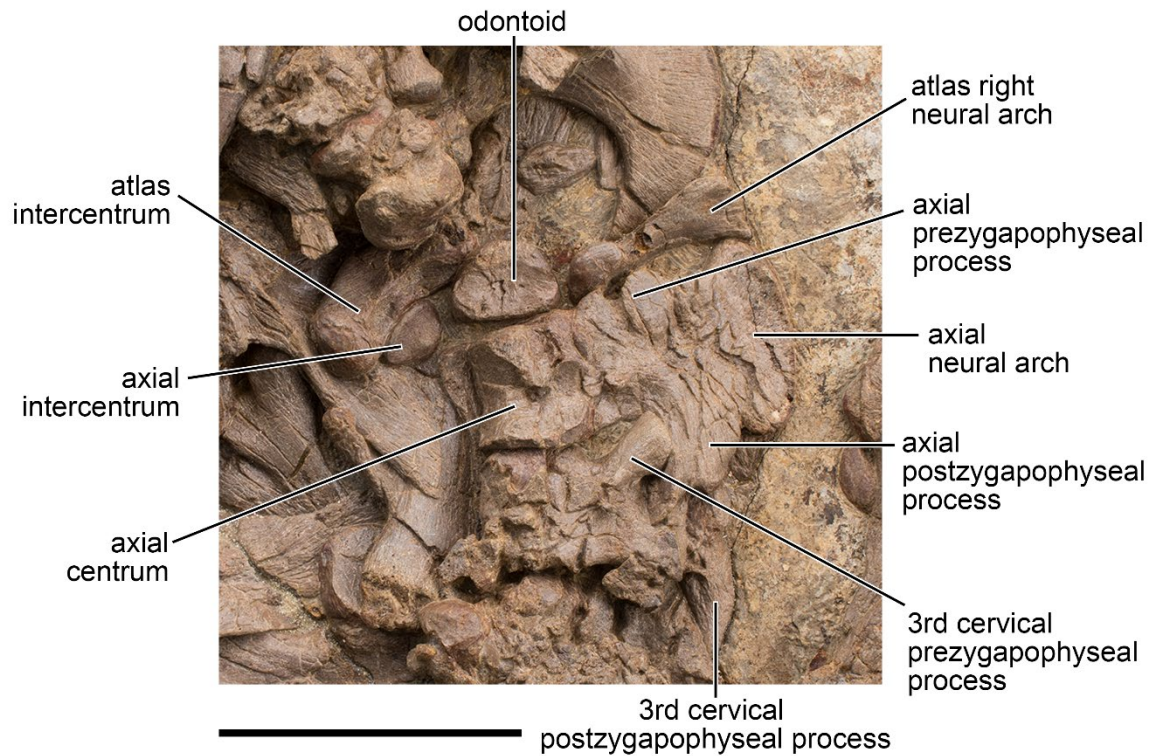


Figure S8 – Lateral view of the first cervical vertebrae of *Haolong dongi* AGM 16793. Scale bar = 5 cm.

Cervical ribs — Fragments of cervical ribs are poorly preserved on the lateral aspect of the neck. Most appear double-headed.

Dorsal vertebrae — Twelve dorsal vertebrae can be identified in AGM 16793 (Fig. 1A). Most of them are disarticulated, their neural arch being separated from their corresponding centrum. This absence of fusion between the centrum and the neural arch indicates the skeletal immaturity of this specimen at the time of its death.

Few details of individual dorsal vertebrae can be determined due to their orientation in the slab, or the presence of overlying elements (pectoral girdle, dorsal ribs). The centra appear cylindrical in lateral view, with transversely compressed sides between the articular surfaces. Their articular surfaces are planar to slightly concave. The centra are roughly as craniocaudally long as dorsoventrally high. They gradually increase in size and become proportionally wider transversely, with an oval cross-section as the series progresses towards the pelvic areas. The transverse processes appear relatively slender and slightly inclined dorsally. As e.g. in *Bolong*¹² and *Iguanodon*⁵³, the neural spines of the dorsals remain relatively low, contrasting with the situation observed in *Mantellisaurus*⁵⁵, in which they are more than 2.5 times

higher than the vertebral centrum and especially in *Ouranosaurus*^{S6}, in which the spine is as much as nine times the height of the centrum.

Dorsal ribs — Approximately 20 dorsal ribs are preserved in articulation (Fig. 1A). The ribs are curved in both transverse and anteroposterior planes. Curvature of the ribs becomes more accentuated posteriorly as the result of greater curvature of the proximal shaft in combination with the increased length of the capitulum. The longest dorsal rib seems to be the 7th one. The capitulum extends almost perpendicular to the shaft, while the tuberculum forms a short articular process that extends in line with the rib shaft. In posterior dorsals the tuberculum becomes further reduced to a simple facet on the dorsolateral corner of the elongated capitulum, as also described in *Jinzhousaurus*¹¹. Because of the marked angulation between the capicular process and the shaft of the rib and the relatively straight shaft of the longest ribs, the rib cage of *Haolong* was likely relatively narrow, contrasting with the wider rib cage in rhabdodontid iguanodontians^{S25}. The proximal shaft of the longest dorsal ribs has a T-shaped cross-section, with a thickened cranio-lateral edge and a narrower caudo-lateral one. Distally, the rib shaft becomes transversely compressed.

Sacrum — The sacrum of AGM 16793 is completely dislocated (Fig. 1A) so that few details can be described. This dislocation indicates that the centra, corresponding neural arches and sacral ribs were not fused, supporting the hypothesis that this specimen was not osteologically mature when it died. As for the dorsal vertebrae, the neural spines are proportionally low.

Caudal vertebrae — Forty-nine caudal vertebrae are preserved in perfect articulation; only the distalmost are missing (Fig. 1A; Fig. S9). The number of caudal vertebrae is rarely known with great precision in dinosaurs, as the distal part of the tail is usually missing. Between 60 and 65 caudal vertebrae are reported in *Tenontosaurus*^{S26}, at least 44 in *Camptosaurus*^{S27}, about fifty in *Iguanodon*^{S3}, more than 45 in *Mantellisaurus*^{S5}, more than 50 in *Ouranosaurus*^{S6}, and between 50 and 70, mainly depending on the species, in hadrosaurids^{S28}. The tail of AGM 16793 represents about half the total length of the body. On the proximal third of the tail, the centra and neural arch are disarticulated, indicating once again the young ontogenetic age of the individual. The centra of the proximal 25 caudals are proportionally higher than long, and sub-quadrangular in lateral view. More distally, the centra become proportionally longer than high, although this elongation starts more distally in *Bolong*: the ratio 'length / height' is 1.45 in *Haolong* and 1.86 in *Bolong*, at the level of the 36th preserved caudal centrum^{S12}. The lateral sides of the centra are slightly depressed. Their ventral side is markedly concave and forms four (two proximal and two distal) large haemapophyseal facets, with the distal facets better developed than the proximal ones. As in *Bolong*, the dorsolateral sides of the proximal 14 centra have an elliptical and rugose articular facet

(fused para-and diapophysis) for the caudal ribs. The fact that the ribs are not fused to the centrum indicates again that AGM16793 was not osteologically mature when it died. On the neural arch, the prezygapophyses are inclined medially, whereas the postzygapophyses are similarly inclined laterally. The neural spines of caudal vertebrae 1-7 are about 1.5 as high as the centra, as also observed in *Bolong*; they are much more elongated in *Bayannurosaurus*^{S2}, *Mantellisaurus*^{S5}, *Brighstoneus*^{S8}, *Comptonatus*^{S29}, *Probactrosaurus*^{S12}, and *Gobihadros*^{S30}. As in *Altirhinus kuzanovi* paratype PIN 3386/9 (also a juvenile)^{S4} and *Bactrosaurus*^{S16}, they are markedly arched distally, contrasting with the straighter and rectangular neural spines on the proximal caudals in *Camptosaurus*^{S27}, *Iguanodon*^{S3}, *Mantellisaurus*^{S5}, *Brighstoneus*^{S8}, *Comptonatus*^{S29}, *Bayannurosaurus*^{S2}, *Bolong*¹², *Jinzhouosaurus*^{S11}, *Probactrosaurus*^{S12}, *Eolambia*^{S31}, and *Gobihadros*^{S30}. The height of the neural spine progressively decreases towards the distal tail of the tail, but only the distalmost caudals are devoid of a neural spine.

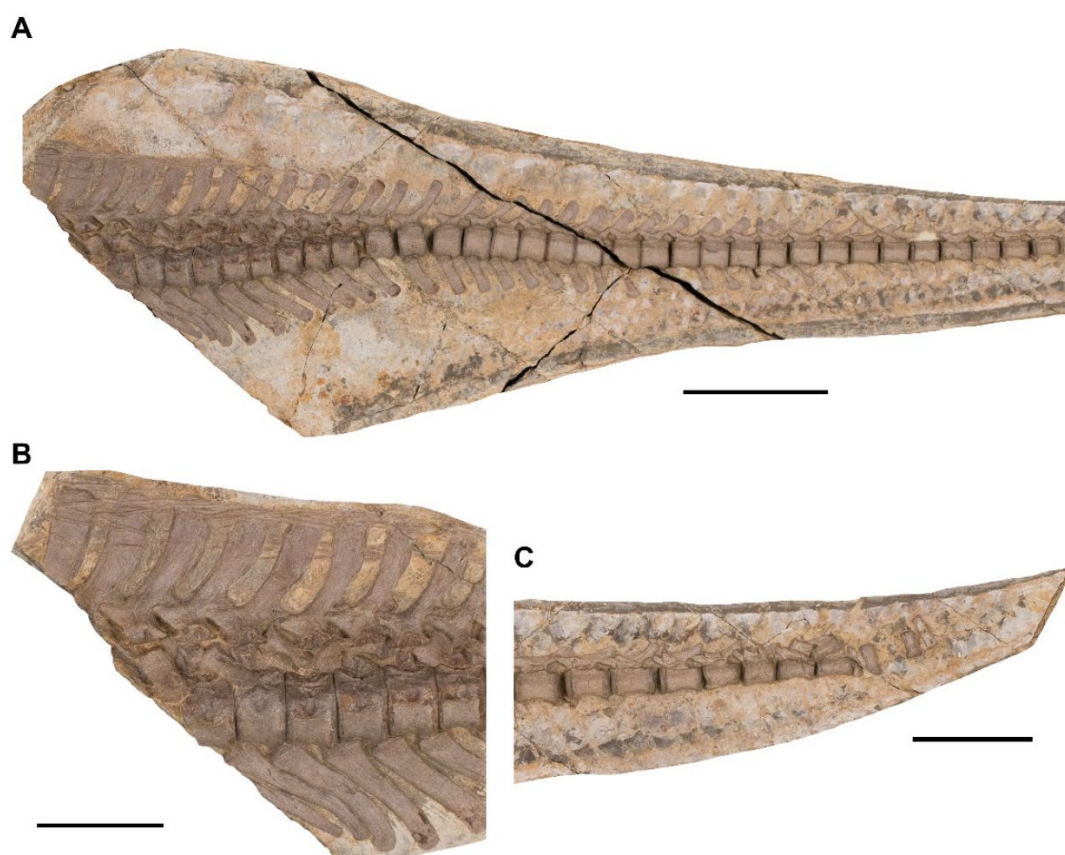


Figure S9 – Lateral view of the tail of *Haolong dongi* AGM 16793 (A), with close-ups of the first proximal (B) and distal (C) caudal vertebrae. Scale bars = 10 cm (A); 5 cm (B-C).

Haemapophyses — About 33 haemapophyses are preserved either articulated or not to the corresponding facets of the centra (Fig. 1A; Fig. S9). Their height gradually lessens towards the distal part of the tail. The first haemapophysis articulates between the third and fourth caudals, whereas, it articulates between caudal vertebrae 2–3 in *Bolong*¹², *Iguanodon*⁵³, *Mantellisaurus*⁵⁵, and lambeosaurines⁵²⁸, between vertebrae 3–4 in *Ouranosaurus*⁵⁶, distal to caudal vertebra 4 or 5 in hadrosaurines⁵²⁸, and between vertebrae 7–8 in *Tethyshadros*⁵²². The seven proximal haemapophyses are craniocaudally thick and closely packed together, leaving no space between their respective bases. On the proximal part of the tail, the chevrons are slightly higher than the corresponding neural spines. Their caudoventral orientation was also apparently equivalent to the caudodorsal angle of the corresponding neural spine. The distalmost chevrons are craniocaudally shorter, with a lobate ventral part.

Ossified epiaxial tendons — In *Haolong*, the ossified epiaxial tendons extend from the proximal dorsals, up to the level of caudal 11 (Fig. 1A; Fig. S9). Because of the taphonomic distortion of the skeleton, we cannot identify the precise origin point in the dorsal vertebrae. In *Bolong*, the tendons extend from dorsal 4 up to about the level of the sixth preserved caudal¹². Similarly, ossified tendons are found from dorsal 3 up to caudal 6 in the hadrosaurid *Brachylophosaurus*⁵³². The ossified tendons extend further distally on the tail in the basal hadrosaurid *Tethyshadros* (from dorsal 4 to caudal 20)⁵²², in the hadrosaurine *Gryposaurus* (from dorsal 4 to caudal 19)⁵³³, and in the lambeosaurine *Corythosaurus*⁵³⁴. In *Iguanodon* and *Mantellisaurus* ossified tendons are present from cervical 10 up to about caudal 20^{53, 55}. As in *Camptosaurus*⁵²⁹, *Iguanodon*⁵³, and *Mantellisaurus*⁵⁵, the epiaxial tendons are arranged in a complex double-layered rhomboidal structure and the tendons extend to the distal portion of the neural spine on the caudal vertebrae. This is also the case in hadrosaurids, in which the epiaxial tendons even form a three-layered lattice⁵³⁵. This arrangement contrasts with the situation in *Bolong*, in which tendons are longitudinally arranged along the epiaxial region of the vertebrae, between the transverse process and the base of the neural spine, and do not extend above the proximal third of the spine. This configuration is the plesiomorphic condition also encountered in *Hypsilophodon*, *Gasparinisaura*, *Parksosaurus*, *Thescelosaurus*, *Dryosaurus*, and *Tenontosaurus*¹².

Appendicular skeleton

Scapula —The left scapula is nearly completely preserved in articulation with the humerus and the coracoid and visible in lateral view; the proximal part of the right one is visible in medial view (Fig. 1A; Fig. S10). Although it cannot be precisely measured, the scapula is much longer than the humerus in AGM 16793. The coracoid facet of the scapula is straight in lateral view and occupies much of the proximal

end of the scapula, with the glenoid forming a deep embayment on the caudoventral corner of this facet. The glenoid is supported posteroventrally by a prominent quadrangular buttress that faces ventrally. The acromial process is particularly prominent and extends dorsally, forming a 90° angle with the scapular blade (Extended Data Fig. 11A-B). This morphology contrasts with the condition in *Bolong*, in which the acromial process gradually merges with the blade^{S12}. In *Jinzhousaurus*, the acromial process, projects mainly laterally and slightly dorsally, more closely resembling the condition in hadrosaurids^{S11}. Between the coracoid suture and the acromial process, the dorsal corner of the proximal plate forms a particularly deep notch, better developed than in *Bolong* and *Jinzhousaurus*. The scapular blade has its minimal height distal to the proximal plate. The ventral margin of the scapular blade is markedly concave in lateral view, although its dorsal border is moderately convex. Consequently, the distal end of the scapula is expanded ventrally. The distal expansion of the scapular blade is better marked than in *Bolong*, *Jinzhousaurus*, *Iguanodon*, *Mantellisaurus*, *Ouranosaurus*, *Altirhinus*, and *Probactrosaurus*, more closely resembling the condition in more derived hadrosauroids such as *Gobihadros*^{S30} and *Bactrosaurus*^{S16}.

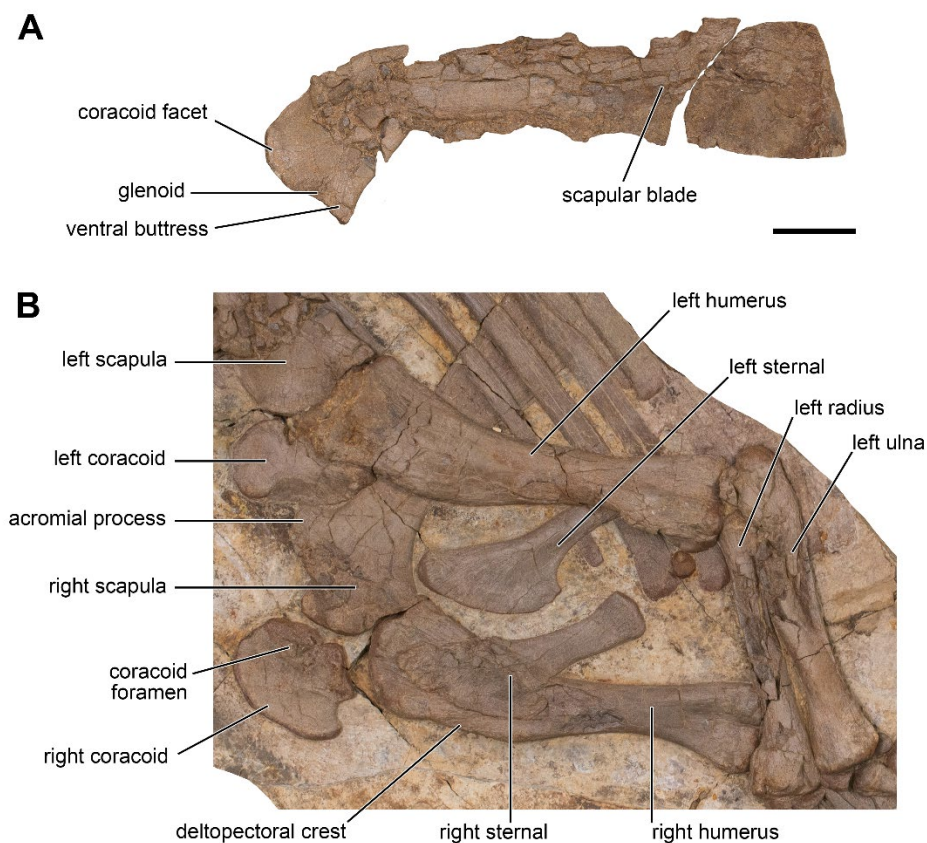


Fig. S10 – A) Left scapula of *Haolong dongi* AGM 16793 in lateral view. B) Left and right coracoids, left and right sternum, left and right humeri and left radius and ulna of *Haolong dongi*

AGM 16793. Scale bar corresponds to 4 cm.

Coracoid — The right coracoid is perfectly preserved in articulation with the scapula and the humerus, whereas the left one is highly deformed. Both elements are not co-ossified with the corresponding scapulae (Fig. 1A; Fig. S10B). As in other non-hadrosaurid iguanodontians, they are rather large, around 18% the length of the scapula, and subquadrate, with an articular surface for the scapula longer than the glenoid. In hadrosaurids, the coracoid is proportionally shorter and the glenoid is equal or longer than the articulation for the scapula^{S36}. On the ventral border of the bone, the coracoid notch is shallow and the coracoid process distinctly shorter than in *Jinzhousaurus*¹¹, *Altirhinus*^{S4}, *Probactrosaurus*^{S12}, and more derived hadrosauroids, more closely resembling the condition in *Camptosaurus*^{S29} and *Ouranosaurus*^{S6}. The coracoid foramen is positioned adjacent to the scapular articulation but is fully enclosed within the coracoids, as in *Jinzhousaurus*¹¹ and *Mantellisaurus*^{S5}, contrasting with the open foramen in *Bolong*¹² and *Iguanodon*^{S3}. On the medial surface of the coracoid this foramen leads into a shallow craniocaudally extending groove that would have communicated with the coracoid groove on the scapula.

Sternal — The proximal part of the left sternal and the distal part of the right one are visible, both in ventral view (Fig. 1A; Fig. S10B). Similar to other ankylopollexian iguanodontians, the sternal is hatchet-shaped, formed by a proximal plate and a distal handle. The medial border of the proximal plate is regularly convex, contrasting with the straighter condition in *Jinzhousaurus*; it is particularly rugose proximally, marking the insertion of a coracosternal cartilage. The distomedial angle of the proximal plate is slightly truncated, although it forms a prominent and diagnostic tab-like midline process in *Jinzhousaurus*^{S11}. The lateral margin of the main plate is smoothly concave as it merges into the distal handle. The sternal handle is elongate, strap-like, with subparallel sides. It is proportionally more robust than in *Iguanodon*^{S3} and *Probactrosaurus*^{S12}, more closely resembling the condition in *Fukuisaurus*^{S17}, *Mantellisaurus*^{S5}, *Ouranosaurus*^{S6}, *Jinzhousaurus*¹¹, and *Altirhinus*^{S4}; its distal end is dorsoventrally flattened, mediolaterally expanded and rugose. The sternal handle is straight, contrasting with the laterally arched process in *Iguanodon*^{S3}.

Humerus — The right humerus is visible in cranial view, whereas the left one is exposed in caudal view (Fig. 1A; Fig. S10B). In general proportions, the humerus of AGM 16793 resembles that of *Probactrosaurus*^{S12} and *Ouranosaurus*^{S6} in being rather slender, contrasting with the more massive one e.g. in *Jinzhousaurus*¹¹. The proximal end is compressed craniocaudally and less expanded mediolaterally than in *Bolong*¹². Unlike in *Bolong*, the humeral head is not particularly salient. The medial side of the humerus is smoothly concave. The deltopectoral crest extends for approximately half the total length of the humerus. Distally, this crest progressively merges with the humeral shaft and it does not form a

prominent 'angle' on the shaft as in hadrosaurids. Distally the humerus slightly expands mediolaterally as it approaches the distal articular surfaces for the radius and the ulna. The radial condyle is mediolaterally wider than the ulnar condyle, but this may be due to postmortem deformation. The intercondylar groove is poorly developed on the cranial side of the humerus.

Ulna —The ulna and radius are described as being held vertically. The ulna is 84 % the length of the humerus and proportionally robust (Fig. 1A; Fig. S10B). With a diameter at midshaft 16% of the total length of the ulna, it resembles the condition in *Bolong* (also 16 %) ¹², *Lurdusaurus* (~ 18 %) ^{S37} and *Jinzhousaurus* (~ 13 %) ¹¹, being proportionally more robust than in *Probactrosaurus* (~ 6%) ^{S12} and *Nanyangosaurus* (~ 9%) ^{S38}. The olecranon process of the ulna is blunt and rounded. The caudal border of the ulna is slightly concave in lateral view, contrasting with the condition in *Bolong*, in which this border is convex because of the development of a prominent keel on the proximal aspect of the ulna ¹². The ulna progressively tapers but is craniocaudally expanded again distally.

Radius — In AGM16793, the radius is 73 % the length of the humerus (Fig. 1A; Fig. S10B), similar to the ratio in *Ouranosaurus* (~ 75 %) ^{S6}, but proportionally longer than in *Bolong* (~ 63%) ¹², *Jinzhousaurus* (~ 64 %) ¹¹ and *Lurdusaurus* (~ 55 %) ^{S37}, and proportionally shorter than in *Mantellisaurus* (~ 80 %) ^{S5}, and *Tethyshadros* (~ 98 %) ^{S22}. However, this ratio seems highly variable in *Iguanodon bernissartensis*, ranging between ~ 64 % and ~ 75 % (pers. obs.). With a diameter at midshaft ~ 12% of the total length of the ulna, the general proportions of the radius of AGM 16793 resemble the condition in *Bolong* (also ~ 12%) ¹² and *Jinzhousaurus* (~ 13 %) ¹¹, being proportionally more robust than in *Probactrosaurus* and *Nanyangosaurus* (both ~ 7%) ¹¹, but more slender than in *Lurdusaurus* (~ 18%) ^{S37}. Between the proximal and distal expansions, the shaft of the radius is circular in cross-section. Because of the craniocaudal expansions of the extremities of these bones, a small gap is present between the radius and the ulna, although clearly less developed than in *Bolong*.

Carpus — Carpal elements are preserved in both hands, although they are usually slightly displaced (Fig. 1A, Fig. S11). The carpals remain separate elements, as in *Bolong* although they are co-ossified in two blocks in *Iguanodon* ^{S3}, *Mantellisaurus* ^{S5}, *Bayannurosaurus* ^{S2}, and *Ouranosaurus* ^{S6}; in *Jinzhousaurus*, they seem to be partly co-ossified ¹¹. The ulnare is a mediolaterally-elongated element that closely fits the cranial part of the distal surface of the ulna. The radiale is located between the distal end of the radius and ungual phalanx I-2. The intermedium is tentatively interpreted as a flattened element that fits against the caudal portion of the articular surface of the radius. Close to the proximal end of the corresponding metacarpals, the five distal carpals are small and dorsoventrally flattened.

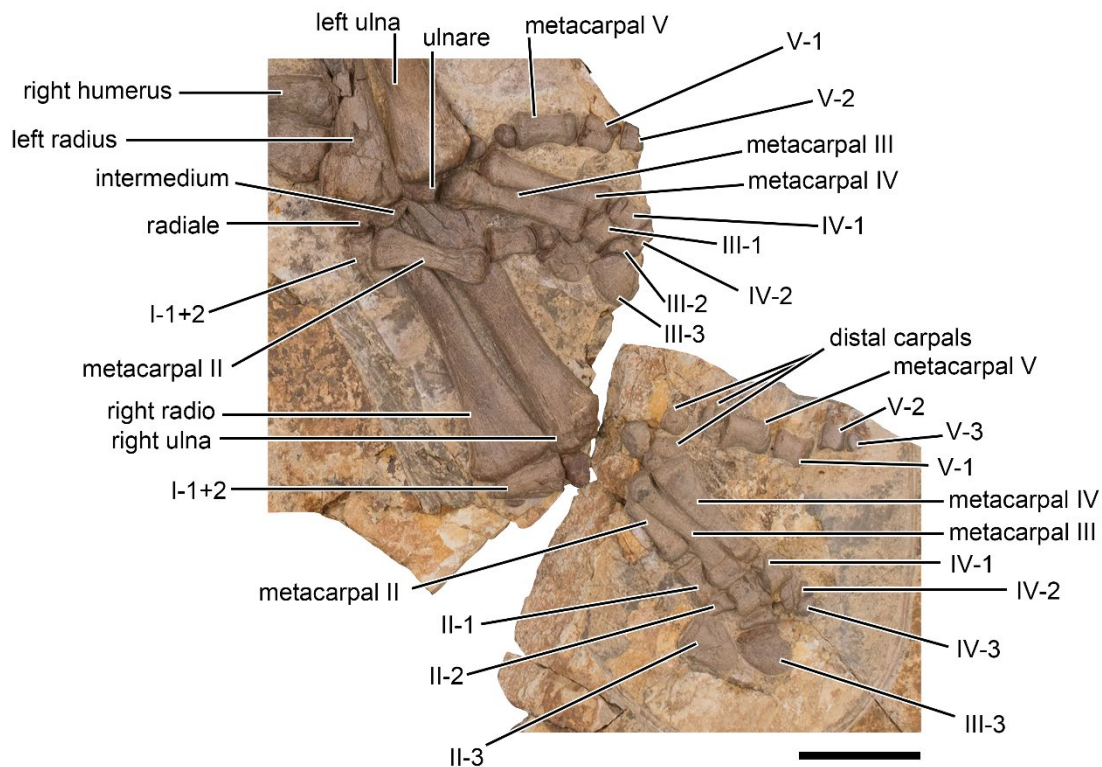


Figure S11 – Right and left hands of *Haolong dongi* AGM 16793. Scale bar = 5 cm.

Metacarpals — The metacarpals are proportionally short (Fig. 1A, Fig. S11): metacarpal III is 27% the length of the humerus, similar to the proportions in *Jinzhousaurus*¹¹, *Bolong* (26%)¹², *Iguanodon* (24%)⁵³, and *Ouranosaurus*⁵⁶. It is proportionally longer in *Mantellisaurus* (35%)⁵⁵, and *Tethyhadros*⁵², but shorter in *Lurdusaurus* (19%)⁵³⁷. However, the metacarpals of AGM 16793 appear more slender (transverse width of metacarpal III at midshaft is ~18 % total length) than in *Bolong* (~27%)¹² and *Jinzhousaurus* (~25%)¹⁷, more closely resembling the condition in *Altirhinus* (~17%)⁵⁴ and *Mantellisaurus* (~15%)⁵⁵.

Metacarpal II is particularly short, about 75% the length of Metacarpal III. It is more slender than metacarpals III and IV and transversely compressed. Its medial side is regularly convex, whereas its lateral side is slightly concave where it was closely bound to metacarpal III.

Metacarpal III is the longest of the series. In craniocaudal view, its medial side is slightly sigmoidal where it closely articulates with metacarpal II. The proximal articular surface is not expanded and weakly convex. The distal articular surface is slightly expanded mediolaterally. Unlike in *Bolong*¹², it is devoid of an intercondylar groove.

Metacarpal IV is nearly as long as metacarpal III but appears more robust because of the development, at mid-height on its dorsal side, of a medial lip that partially covered metacarpal III, reinforcing the attachment between these metacarpals. The proximal articular surface is well expanded and mediolaterally convex. The distal articular surface is more reduced than the proximal one and convex. There is no trace of an intercondylar groove.

Metacarpal V is the shortest of the series, about 43% the length of metacarpal III. Its proximal articular surface is slightly expanded and shallowly concave. Its distal articular surface is also slightly expanded, broadly convex and devoid of an intercondylar groove.

Manus digits — The phalangeal formula of the manus of AGM 16793 is 2-3-3-3-3 (Fig. 1A, Fig. S11), as in *Mantellisaurus*⁵⁵; the formula is 2-3-3-(2+)-4 in *Bolong*¹², 2-3-3-?3-?4 in *Jinzhosaurus*¹¹, 2-3-3-2-4 in *Iguanodon*⁵³ and 0-3-3-2-0 in *Tethyhadros*⁵²². In general, the proximal and intermediate phalanges are less stocky than in *Bolong*, more closely resembling the proportions in *Jinzhosaurus*, *Iguanodon*, and *Mantellisaurus*.

The first phalanx of digit I is a thin disk-shaped element that seems to be completely co-ossified with the ungual phalanx. The latter is quite characteristic for basal hadrosauriforms, being straight, triangular, and mediolaterally compressed, as in *Bolong*¹², *Jinzhosaurus*¹¹, and *Altirhinus*⁵⁴. Ungual grooves are well developed on either side of the dorsal surface and supported by a prominent shelf. In *Iguanodon*⁵³, *Mantellisaurus*⁵⁵, and *Ouranosaurus*⁵⁶, the pollex is more conical and spike-like.

Phalanx II-1 is the longest intermediate phalanx, but is particularly slender, contrasting with the stocky phalanx II-1 in *Bolong*¹², and particularly in *Jinzhosaurus* (in the latter, phalanx II-1 is wider than long in dorsal view)¹¹. It is trapezoidal in dorsal view, with dorsoventrally convex proximal and distal articular surfaces, unlike in *Bolong*. Phalanx II-2 is short, wider than long. The lateral border of this phalanx is longer than its medial one, so its distal articular surface is oblique and the ungual likely oriented medially. Its proximal articular surface is cup-shaped, whereas its distal surface is dorsoventrally convex. The ungual is dorsoventrally flattened and lanceolate in dorsal view. Unlike in *Bolong*, it is distinctly smaller than the ungual for digit I. The ungual grooves are deep on either side of the dorsal surface, limiting a triangular central surface.

Phalanx III-1 is much stouter than the corresponding phalanx II-1 but, unlike in *Jinzhosaurus*, it remains longer than wide in dorsal view. It is also proportionally longer (~ 26 % the length of metacarpal III) than in *Jinzhosaurus* (~ 16.5 %)¹¹, more closely resembling the condition in *Bolong* (~ 25%)¹². Phalanx III-2 is extremely shortened and nearly triangular in dorsal view, with a mesial border

much shorter than the lateral one, deflecting the ungual phalanx medially, as also observed in digit II. The ungual phalanx III-3 has the same size as II-3 and is similarly hoof-like and dorsoventrally flattened, contrasting with the more elongated ungual II-3 in *Bolong*¹². The ungual is distinctly asymmetrical in dorsal view, with a convex medial border and a concave lateral one. The ungual grooves are less clearly marked than on ungual II-3.

Phalanx IV-1 is a slightly reduced version of phalanx III-1. Its distal articular surface is dorsoventrally convex. It invades the dorsal side of the phalanx and forms a well-developed intercondylar groove. Phalanx IV-2 is quite shortened, but more symmetrical in dorsal view than phalanges II-2 and III-2. The ungual phalanx of digit IV is much more reduced than those for digits II and IV, forming a thin disk-shaped element, with a depressed dorsal surface.

Digit V has three phalanges, as in *Iguanodon*. The first phalanx is robust and quadrangular in dorsal view, with a clearly everted distolateral corner. This latter character is likely not pathological as it can be observed on both hands. The dorsal surface of digit V is shallowly concave, whereas its distal articular surface is slightly convex dorsoventrally. However, unlike in *Bolong*, it does not form a shallow intercondylar groove. The second phalanx is about 2/3 the length of the first phalanx and trapezoidal in dorsal view. The ungual phalanx closely resembles that of digit IV; its dorsal margin forms a depressed central area surrounded by a well-defined continuous ridge.

Ilium — The right ilium is displaced above the sacrum and is visible in lateral view (Fig. 1A; Fig. S12A). The rod-like preacetabular process is remarkably narrow dorsoventrally and almost straight, resembling the condition in *Probactrosaurus*^{S12}. Unlike in *Jinzhousaurus*, its ventral edge is particularly thin. The iliac body is dorsoventrally high and craniocaudally short. The pubic peduncle is subtriangular in cross-section and appears less prominently developed than in other non-hadrosauroid iguanodontians. The ischiadic peduncle forms a large boss-like structure on the lateral side of the iliac body. Between both ventral peduncles, the dorsal margin of the acetabulum forms a shallow embayment. The incomplete postacetabular process is dorsoventrally high, subtriangular in lateral view, contrasting with the remarkably narrow postacetabular process in *Bolong*¹². Unlike in *Jinzhousaurus*¹¹, the brevis fossa is not visible in lateral view along the ventral edge of the postacetabular process. The dorsal margin of the ilium is transversely thickened, forming a rounded and continuous ridge along its lateral side. However, unlike in *Iguanodon*^{S3}, *Mantellisaurus*^{S5}, *Altirhinus*^{S4}, *Eolambia*^{S39}, *Tethyshadros*^{S22}, and hadrosaurids^{S28}, the dorsal margin does not really overhang the lateral surface of the blade to form a supraacetabular process or similar structure.

Ischium — Both ischia are partly visible (Fig. 1A, Fig. S12B). The proximal part of the right one is hidden by the sacrum. As usual in iguanodontians, the proximal part of the ischium is dorsoventrally expanded, transversely flattened, and triradiate. The iliac ramus appears particularly expanded, forming a 100° angle with the ischial shaft. The pubic ramus is incompletely preserved. As also observed in *Bolong*¹², the shaft is mediolaterally compressed and only slightly curved ventrally. The dorsoventral height of the shaft gradually increases towards its distal end, terminating as a moderately expanded 'knob'. In *Jinzhousaurus*, the ischial shaft maintains an approximately constant height along its length, except for the distal 'knob'¹¹.

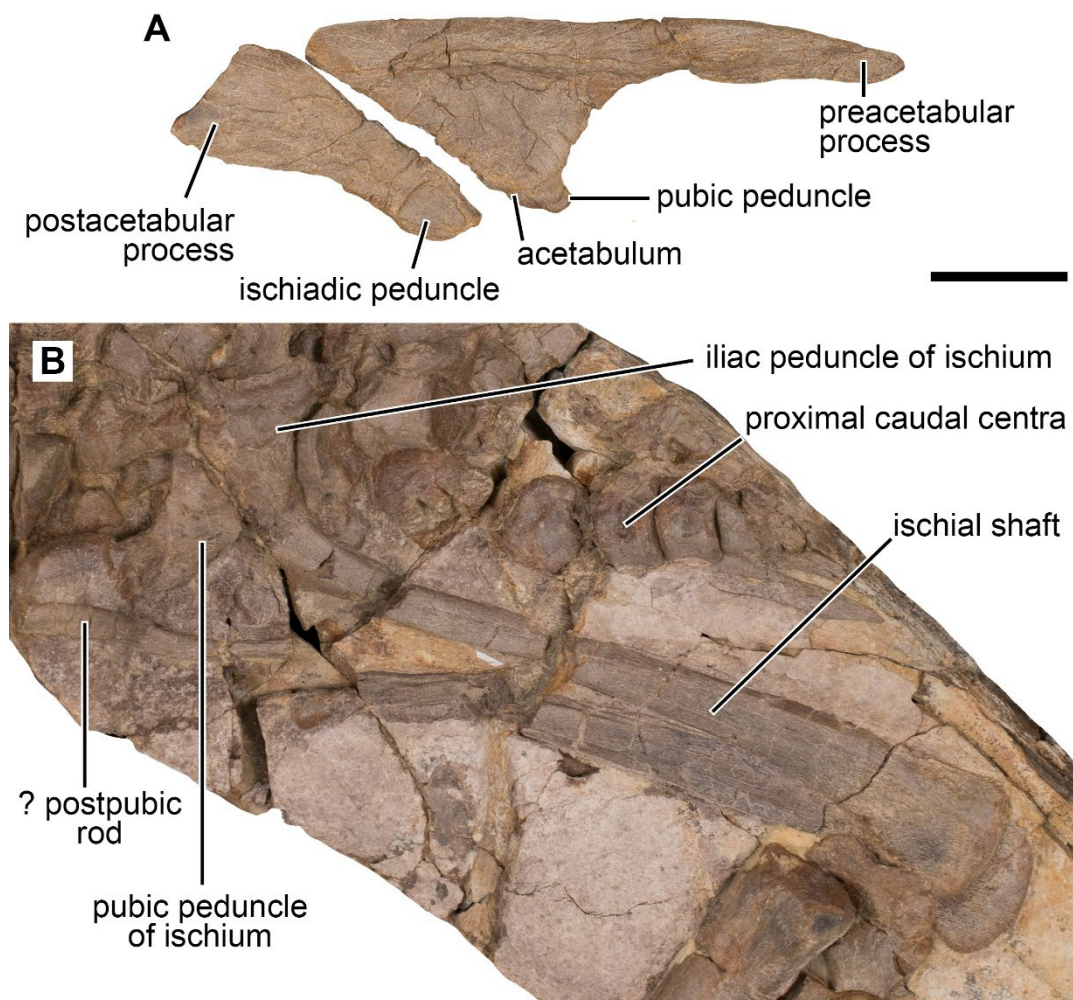


Figure S12 – A) Right ilium of *Haolong dongi* AGM 16793 in lateral view. B) Left and right ischia and pubic rod of *Haolong dongi* AGM 16793. Scale bar = 5 cm.

Pubis — An elongated and sigmoidal piece of bone between the proximal parts of the ischia is tentatively identified as a postpubic rod (Fig. S12B). The remainder of the pubis is not visible.

Femur — The left femur is visible in caudolateral view (Fig. 1A, Fig. S13A). It is rather robust, contrasting with the more gracile one in *Mantellisaurus*⁵⁵ and *Ouranosaurus*⁵⁶. It is pillar-like and perfectly straight, contrasting with the condition in *Bolong*¹² and *Jinzhousaurus*¹¹, in which the distal part of the femur is slightly recurved caudally. The femoral head protrudes medially and slightly dorsally. The fingerlike lesser trochanter terminates well below the apex of the wide and rounded greater trochanter. The lesser and greater trochanters are separated by a narrow cleft. Above the mid-height of the shaft, a prominent triangular fourth trochanter projects from the caudomedial edge of the femur. The distal end of the femur is slightly expanded transversely with respect to the shaft. The distal condyles are prominently expanded caudally; the medial condyle is much larger and more robust than the lateral one. Caudally, each distal condyle supports a sub-rectangular epicondyle; these epicondyles are separated on the midline by a narrow and deep flexor sulcus, which extends proximally along the caudal side of the femoral shaft as a triangular furrow.

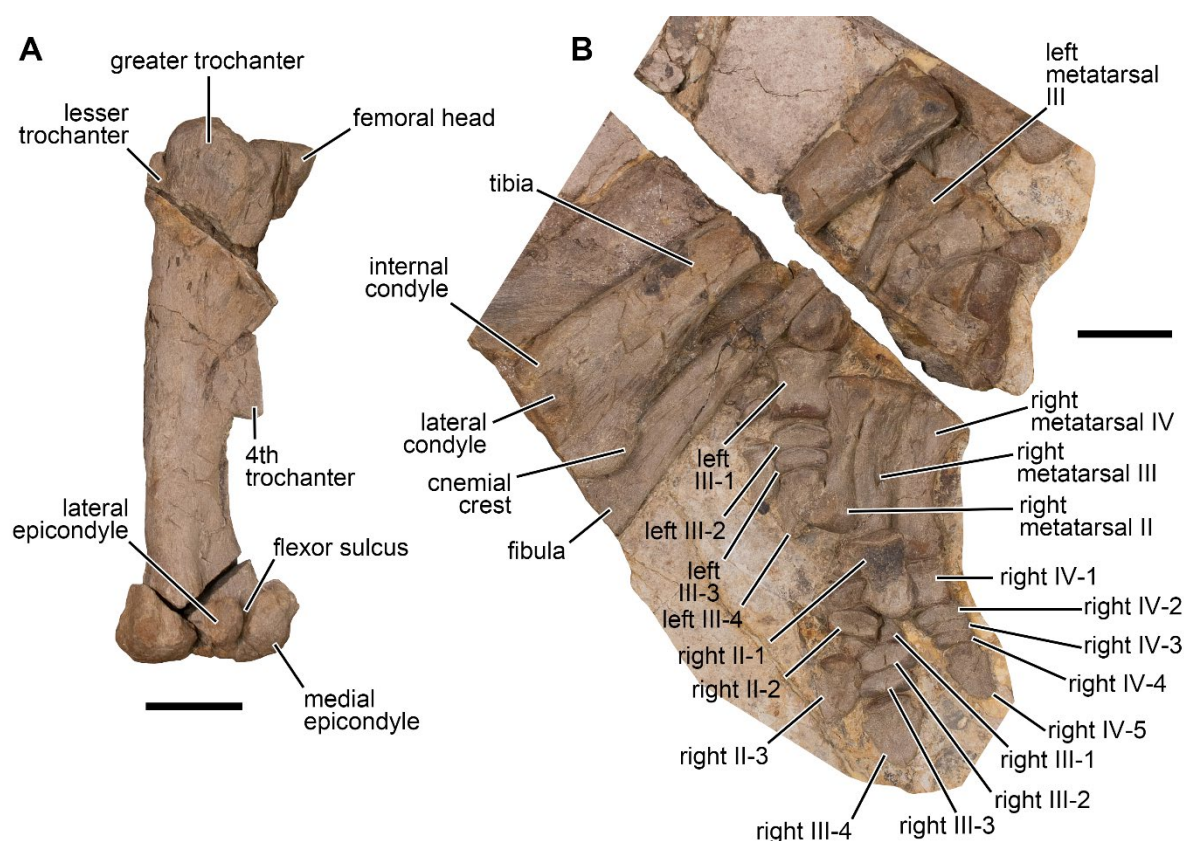


Figure S13 – A) Left femur of *Haolong dongi* AGM 16793 in laterocaudal view, the proximal region is arbitrarily positioned next to the breakage. B) Left tibia and fibula, and left and right foot elements of *Haolong dongi* AGM 16793. Scale bars correspond to 5 cm.

Tibia — The left tibia can be observed in lateral view (Fig. 1A, Fig. S13B). As in most advanced iguanodontians, it is slightly shorter than the femur (~90%). The proximal head of the tibia is enlarged craniocaudally. The cnemial crest is short and does not really extend along the tibial shaft. The caudal corner of the proximal part of the tibia forms a small internal condyle separated by a deep and narrow groove from the much larger lateral condyle. The tibial shaft is robust, straight, and ovoid in cross-section. It forms a prominent lateral ridge that extends distally to form the lateral corner of the external malleolus. The articular surface of the prominent lateral malleolus is turned toward the caudomedial side of the tibia. The internal malleolus is, more prominent medially, with an articular surface that is turned toward the craniolateral side of the tibia.

Fibula — The left fibula is visible in medial view (Fig. 1A, Fig. S13B). It is more robustly built than in *Mantellisaurus* and *Probactrosaurus*, more closely resembling the condition in *Bolong*¹². Proximally, the fibula is craniolaterally expanded and transversely compressed, with a craniocaudally concave medial side. The fibular shaft progressively narrows distally and its distal end forms a moderately developed and slightly everted boot-like structure, which articulated against the craniolateral edge of the distal end of the tibia.

Astragalus — The left astragalus is visible in proximal view. It has a quadrangular outline and is completely unossified with the distal tibia and fibula. The cranial ascending process of the astragalus is particularly well developed, triangular, and distinctly skewed medially.

Metatarsals — The left foot is incomplete, with only digit III preserved in articulation. On the opposite, the right foot is fairly complete, articulated, and visible in ventral view (Fig. 1A, Fig. S13B). Metatarsals II-IV are closely appressed to each other, forming a single functional unit. The ratio ‘metatarsal III / femur’ is 0.37, closely resembling the condition in *Iguanodon* (0.39)⁵³, *Mantellisaurus* (0.37-0.39)⁵⁵, (0.37)⁵⁶, *Probactrosaurus* (0.37; P.G., pers. obs.), *Tenontosaurus* (0.36)⁵⁴⁰, *Nanyangosaurus* (0.37)⁵³⁸, *Tethyshadros* (0.35)⁵²², *Edmontosaurus* (0.37-0.41)⁵⁴¹, and *Corythosaurus* (0.37-0.4)⁵⁴¹, but contrasting with the proportionally shorter metatarsals in *Bolong* (0.18)¹².

Metatarsal II is the shortest and the most slender of the series. Its proximal articular end is expanded towards its plantar side, whereas its shaft is strongly constricted. Its plantar side appears keeled. Its distal end expands to form a large saddle-shaped articular surface for the first phalanx.

Metatarsal III is the longest of the series. It is quadrangular in cross section, with a flattened ventral side. Proximally, its lateral side forms a wide, deep, and triangular depression for the tight articulation with metacarpal IV.

Unlike in *Bolong*, metatarsal IV is more robust than metatarsal III. It is distinctly bowed towards the medial side of the foot, with a convex medial border that partly covers dorsally the shaft of metatarsal III. It is much more slender than metatarsal III and its distal end is only slightly expanded dorsoventrally and smoothly convex.

Pedal phalanges — The phalangeal formula of the pes of AGM 16793 is ?-3-4-5, as it is usual in iguanodontians^{S42} (Fig. S13B). The proximal phalanges of digits 2-4 are similar in shape. They are rather robust but, unlike in *Bolong*¹², they remain proximodistally longer than mediolaterally wide, more closely resembling the condition in *Mantellisaurus*^{S5} and *Probactrosaurus*^{S12}. The short shaft is mediolaterally constricted between the proximal and distal articular surfaces. The distal articular surface is broad, convex, with a shallow intercondylar groove that slightly extends on the dorsal (extensor) side of the phalanx. The middle phalanges are all short disk-like elements. The ungual phalanges are robust and arrowhead-shaped in ventral view, resembling the condition in *Bolong*¹². They are not as proximodistally shortened and genuinely hoof-shaped as in the majority of hadrosaurids^{S28}. From their thick proximal end, the ungual phalanges becomes dorsoventrally flattened towards their tip and their distal end appears slightly arched ventrally. The distal end of the unguals is less blunt than in *Iguanodon*^{S3} and *Mantellisaurus*^{S5}.

2. Taxonomical validity of *Haolong dongi* and evidence for endemism in iguanodontian dinosaurs:

Given that *Haolong dongi*, *Jinzhousaurus yangi*, and *Bolong yixianensis* all three come from the same Yixian formation, and that they cluster closely in the resulting phylogenetic analysis, it is therefore perfectly legitimate to wonder whether *Haolong* might not be a juvenile of one of the other taxa.

Table S1 recapitulates the main osteological differences between the three basal hadrosauroids present in the Yixian Fm. About thirty characters could be identified, concerning all regions of the skeleton. Because of the small sample, it is of course impossible to accurately evaluate the intraspecific variation of each of them. However, ontogenetic studies reveal that, in hadrosaurids, the most important ontogenetic changes concern the orbit to skull size, the premaxillae, the nasals, the supraoccipital, the robustness of femora and tibiae, and the proportions of the limb segments related to changes in the preferred stance^{S43-S45}. Consequently, a great number of the osteological differences between *Haolong dongi*, *Jinzhousaurus yangi*, and *Bolong yixianensis* also concern bones that are regarded as usually stable during ontogeny in Iguanodontia (e.g. most bones of the middle or caudal part of the skull, vertebrae, pectoral and pelvic girdles,...)^{S43-S44}. It is therefore likely that most of the listed differences between the three holotypes support their taxonomic distinction rather than ontogenetic variations.

An early juvenile iguanodontian specimen was also described from the Yixian Fm of Ningcheng County (Nei Mongol, China) and tentatively identified as *Bolong yixianensis*^{S46}. However, we prefer to refer it to as Hadrosauroidea indet., as no undeniably diagnostic character can be identified in this very young specimen.

Table S1. Main osteological differences between the holotype specimens of the three basal hadrosauroid dinosaurs identified so far in the Yixian Fm of Liaoning Province (China). AGM: Anhui Geological Museum, Hefei City, Anhui Province; IVPP: Institute of Vertebrate Paleontology and Paleoanthropology; YHZ: Yizhou Fossil Museum, Yixian City, Liaoning province (P.R. China).

Character	<i>Haolong dongi</i> AGM 16793	<i>Jinzhouosaurus yangi</i> IVPP V12691	<i>Bolong yixianensis</i> YHZ-001
External naris proportion (% preorbital length)	26%, elongated internarial septum	45%	38%
Nasal / lacrimal contact	yes	no	no
Ventral deflection of premaxillary oral margin	limited	limited	more important
Rostral tip of maxilla	not down-turned	not down-turned	distinctly down-turned
Dorsal process of maxilla in lateral view	at mid-point of the bone	caudal to mid-point of the bone	caudal to mid-point of the bone
Antorbital fenestra	open	not visible in lateral view	not visible in lateral view
Additional antorbital foramen	open	absent	closed depression
Buccal emargination on maxilla	slight, limited dorsally by a series of foramina	Dorsal boundary limited by an acute ridge	slight, limited dorsally by a series of foramina
Smaller foramina piercing the lacrimal	2	1	1
Postorbital shape in lateral view	triangular, with short jugal and squamosal processes	longer jugal and squamosal processes	longer jugal and squamosal processes
Rostral tip of dentary, in lateral view	close to ventral margin of dentary	close to ventral margin of dentary	above ventral third of dentary
Coronoid process of dentary	slightly inclined caudally	slightly inclined caudally	forms a 90° angle with the axis of dentary
Primary ridge on maxillary teeth	oriented labially	oriented labially	deflected distally
Ratio 'length /height' of 36th caudal centrum	1.45	1.36	?
Neural spines of proximal caudals	arched distally	rectangular	rectangular
Acromial process of scapula	forms a 90° angle with the scapular blade	gradually merges with the scapular blade	projects mainly laterally and slightly dorsally
Distal expansion of scapular blade	well-marked	ventral and dorsal margins of scapula remain +/- parallel	ventral and dorsal margins of scapula remain +/- parallel
Coracoid foramen	closed	closed	open
Distomedial angle of sternal proximal plate	slightly truncated	forms a tab-like medial process	?
Radius/humerus length ratio	73 %	64 %	63 %
Carpals	separate	partly co-ossified	separate
Transverse width of metacarpal III at mid-shaft	18 % total length	25 % total length	27 % total length
Phalangeal formula of manus	2-3-3-3-3	2-3-3-?3-?4	2-3-3-(2+)-4

Manual phalanx II-1	slender	stocky, wider than long in dorsal view	stocky
Relative length of manual phalanx III-1	26 % the length of metacarpal III	16.5 % the length of metacarpal III	25 % the length of metacarpal III
Preacetabular process of ilium	straight and rod-like	dorsoventrally higher and curved	?
Pubic peduncle of ilium	short and triangular in lateral view	distinctly longer	?
Postacetabular process of ilium	dorsoventrally high and triangular in lateral view	dorsoventrally high and triangular in lateral view	dorsoventrally narrow
Brevis shelf	not visible in lateral view	visible in lateral view	not visible in lateral view
Femur	pillar-like and perfectly straight	distal part slightly recurved caudally	distal part slightly recurved caudally
Ratio 'metatarsal III / femur'	0.37	?	0.18
Metatarsal IV	More robust than metatarsal III	?	less robust than metatarsal III
Proximal pedal phalanges	proximodistally longer than mediolaterally wide	?	proximodistally shorter than mediolaterally wide

The presence of several taxa of closely-related iguanodontian dinosaurs within the same formation, as exemplified by the Yixian Formation is usual. Recent and on-going researches suggest that Early Cretaceous iguanodontians from Europe are characterized by their endemism and wider diversity, as exemplified by the late Hauterivian-Barremian faunas in Spain, from which *Iguanodon galvensis* (lower Barremian)⁵⁴⁷, *Magnamanus soriaensis* (upper Hauterivian–lower Barremian)⁵⁴⁸, *Morelladon beltrani* (Barremian)⁵⁴⁹, and *Portellsaurus sosbaynati* (early Barremian–early late Barremian)⁵⁵⁰ have been described. The Barremian to early Aptian deposits of the Isle of Wight have also yielded a particularly diversified iguanodontian fauna, including *Mantellisaurus atherfieldensis*⁵⁵¹, *Brighstoneus simmondsi*⁵⁸, *Comptonatus chasei*⁵²⁹, and *Istiorachis macarthurae*⁵⁵². The quite limited late Barremian-early Aptian Iguanodon Sinkhole at Bernissart has also yielded two iguanodontian taxa. The taxonomic status of the most gracile form is still debated: to simplify, it has been successively identified as *Iguanodon mantelli*⁵⁵³, *Iguanodon atherfieldensis*⁵⁵, *Dollodon bampergi*⁵⁵⁴, and *Mantellisaurus atherfieldensis*⁵⁵⁵. Ongoing investigations (FB, PG, in prep.) highlight significant differences between the gracile iguanodontian from Bernissart and the type material of *Mantellisaurus atherfieldensis* from the Isle of Wight, suggesting that it belongs to a different taxon ('*Dollodon bampergi*'), which is until now only known in Bernissart. This observation reinforces the hypothesis of a high endemism for the iguanodontian taxa in the Barremian-lower Aptian of Europe. The geographical range of the robust form from Bernissart, named *Iguanodon bernissartensis* appears to be wider, however, as this species has so far also been identified in the Wessex Formation of the Isle of Wight, in

the Hastings Beds, Weald Clay, of West Sussex (UK), in the Weald Clay of Surrey (UK), in the Potters Sands of Bedfordshire (UK), in the Arcillas de Morella Formation of Castellon (Spain), in the Wealden of Nordrhein-Westphalen (Germany), in the Argiles à plicatules Formation and Grès et sables piquetés of Haute Marne (France), and in the Argiles ostréennesand, Grès et sables piquetés of Meuse (France)^{S42}. However, at least part of these identifications as *I. bernissartensis* must be clearly re-evaluated, as they were made in were made at a time when the paradigm was that small Barremian iguanodontian specimens belonged to *Iguanodon atherfieldensis*, while larger ones belonged to *I. bernissartensis*. Therefore, it cannot be excluded that *I. bernissartensis* is partly a wastebasket taxon for the robust iguanodontian specimens from Barremian-lower Aptian deposits of western Europe and that their diversity is consequently still underestimated.

It is now well established that Late Cretaceous iguanodontians had also relatively strict ecological and geographical preferences^{S56-S58}. Important endemism and partitioning of hadrosaurid faunas are particularly well documented in the Campanian Dinosaur Park Formation of Alberta, Canada^{S59-S61}, in the Horseshoe Canyon Formation of Alberta^{S62}, and in the Maastrichtian Udurchukan/Yuliangze formations of northeastern Asia^{S63-S64}.

3. Character description :

PREDENTARY

1. Predentary, overall shape of oral portion in dorsal view: subtriangular, comes to a point without a distinct rostral portion (0); arcuate, rounded rostrolateral corners (1); subrectangular, squared corners and straight, well demarcated rostral portion (2).
2. Predentary, directions of lateral margins of lateral processes relative to each other in dorsal and ventral views: divergent (0); parallel (1).
3. Predentary, morphology of ventromedial process: undivided (0); short indentation and deep undivided portion (1); long indentation and shallow undivided portion (2).
4. Predentary, dorsomedial process: absent (0); present (1).
5. Predentary, denticles in adults lateral to the median denticle (not included in the count): denticles absent (0); present (1).
6. Predentary, denticle morphology: large, conical median denticle with one or two prominent conical denticles of subequal size adjacent to the median denticle on both sides and smaller, tab-like denticles on lateral processes (0); rostrocaudally compressed prong-like denticles that increase in size towards the midline of the predentary (1); rostrocaudally compressed prong-like denticles of equal size (2).
7. Predentary, extension of denticulate margin: denticles absent (0); denticles extending on lateral process (1); denticles limited to the rostral margin (2).
8. Predentary, development of a lateral shelf on the dorsal side of the lateral process: absence of shelf, short and shallow groove, limited to the laterocaudal region of the lateral process (0); short and shallow shelf limited to the laterocaudal region of the lateral process (1); short and well-incised shelf that is wider near the rostrolateral corner of the predentary (2); shelf extremely narrow mediolaterally and very long rostrocaudally (3); shelf rostrocaudally long, deeply incised and mediolaterally broad, forming half of the mediolateral breadth of the lateral process and becoming wider distally (4).
9. Ridge on the dorsal lingual, predentary keel-like process: the process lacks a prominent median ridge on the lingual side of the rostral region of the predentary, and, if present, the former forms and projects caudally from the caudal margin of the predentary rostral region (0); the process has a well-developed ridge on the lingual surface of the rostral segment of the predentary, from which the former extends further caudally to lie dorsal to the dentary symphysis (1).

10. Prementary, grooves on either side of midline on rostral surface, extending ventrolaterally to dorsomedially: absent (0); present (1).
11. Prementary, ratio between the dorsoventral depth of the rostral face (excluding the median ventral process) and the length of the lateral process: ratio greater than 0.38 (0); ratio of 0.38 or less (1).

DENTARY

12. Dentary, orientation of symphyseal region in lateral view: ventral surface of symphyseal region visible in lateral view, articulation site for ventromedial process of prementary faces ventrolaterally (0); ventral surface of symphyseal region not visible in lateral view, articulation site for ventromedial process of prementary faces ventrally (1).
13. Dentary, lingual projection of the symphyseal region (measured as a ratio between the labiolingual extension of the symphyseal region and the maximum labiolingual width of the dentary): ratio up to 1.65 (0); ratio greater than 1.65 and up to 2.85 (1); extremely elongated rostral end of the dentary, ratio greater than 2.85 (2).
14. Dentary, ratio between the length of the proximal edentulous slope of the dentary and the distance between the rostralmost tooth position and the caudal margin of the coronoid process: less than 0.20 (0); ratio between 0.20 and 0.45 (1); ratio greater than 0.45 (2).
15. Dentary, medial or lateral profile of the dorsal margin of the rostral edentulous region for articulation with the prementary: ranging from having a very subtle concavity to straight (0); having a well-pronounced concavity. (1).
16. Dentary, orientation of the longitudinal axis of the tooth row relative to the lateral side of the bone: diagonal axis, directed rostromedially and forming approximately 15° with the lateral side of the dentary (0); axis parallel to the lateral side of the dentary (1).
17. Dentary, lingual arching of the occlusal plane: bowed medially at mid-length (0); bowed medially along caudal half (1); straight (2).
18. Dentary, morphology of tooth alveoli: alveoli shaped by dentary teeth (0); alveoli with parallel vertical walls (1).
19. Dentary, caudal-most extent of tooth row: rostral to base of coronoid process (0); medial to coronoid process but still rostral to longitudinal axis of the process (1); even with longitudinal axis of the coronoid process (2); caudal to longitudinal axis of the coronoid process but still rostral to the caudal margin of the process (3); caudal to the base of the coronoid process (4).

20. Dentary, shape in lateral or medial view: tapers rostrally (0); dorsal and ventral margins are parallel (1); deepens rostrally (2).
21. Dentary, bulge along ventral margin directly ventral to the base of the coronoid process: absent (0); present (1).
22. Dentary, bulge on the lateral surface ventral to the coronoid process that gives rise to the process: absent (0); present (1).
23. Dentary, separation between the tooth row and the coronoid process: the coronoid process is laterally offset (but nearly in contact) with the tooth row, lacking a platform in between the tooth row and the base of the process (0); the coronoid process is laterally offset relative to the tooth row, with the presence of a concave platform or, in some cases, a laterodorsal concave slope separating the base of the process from the dental battery (1).
24. Dentary, orientation of coronoid process: caudally inclined (0); vertical (1); rostrally inclined (2).
25. Dentary, expansion of dorsal end of coronoid process: slightly expanded rostrocaudally, with very limited development of rostral and caudal expansions resulting in an apex that is taller than wider (0); well-developed expansion (1).
26. Dentary, location of dorsal expansion of coronoid process: along rostral edge only (0); along rostral and caudal edges (1).
27. Dentary: deflection of the rostral ventral margin: nearly straight, angle less than 17° (0); moderately deflected, angle between 17° and 25° (1) strongly deflected, angle greater than 25° (2).

SURANGULAR

28. Surangular, surangular foramen: present (0); absent (1).
29. Surangular, external mandibular fenestra: small foramen (“accessory foramen”) on surangular near suture with dentary (0); absent (1).
30. Surangular, shape of contact with angular in lateral view: inclined rostradorsal to caudoventral (0); sinuous (1); horizontal (2).
31. Surangular, morphology of the rostradorsal process: rostrocaudally thick process extensively exposed in lateral view (0); rostrocaudally reduced in thickness, strap-like and wedging dorsally into a thin sliver that becomes concealed in lateral view by the dorsal half of the caudal margin of the coronoid process (1).
32. Surangular, lateral curvature of the caudal process: present, process laterally recurved (0); absent, process nearly straight rostrocaudally (1).

ANGULAR

33. Angular, exposure in lateral view: present, groove on ventral margin of surangular for articulation with angular (0); absent, articulation with surangular occurs on the medial surface of that bone (1).

PREMAXILLA

34. Premaxilla, mediolateral expansion of the oral margin (measured as the ratio between the maximum mediolateral width of the premaxilla and the minimum width at the narrowest point or post-oral constriction): premaxillae not transversely expanded, snout comes to a point (0); premaxilla expanded and snout squared, but ratio less than 1.65 (1); ratio between 1.65 and 2 (2); very wide, with a ratio greater than 2 (3). Character treated as ordered.
35. Premaxilla, position of the premaxillary oral margin relative to the occlusal plane of the dentition: ventral inflection absent, oral margin even with ventral margin of maxilla (0); premaxillary margin slightly ventrally offset from occlusal plane (approximately, the dorsoventral distance between the occlusal plane and the level of the premaxillary oral margin is less than the mean depth of the dentary) (1); very strongly deflected ventrally (approximately, the dorsoventral distance between the occlusal plane and the level of the premaxillary oral margin is equal to or larger than the mean depth of the dentary) (2).
36. Premaxilla, morphology of caudolateral corner of oral margin in lateral view: in contact with maxilla (0); free and gently curved (1); free and angular (2).
37. Premaxilla, degree of expansion and folding of the oral margin: everted rim absent (0); moderately expanded border, becoming thinner towards the parasagittal plane of the snout (1); folded caudodorsally into a thin recurved margin (2); ventrally deflected and dorsoventrally expanded, forming a very thick 'lip-like' margin (3).
38. Premaxilla, transverse ridge of thickened bone caudal to oral margin, separated from the oral margin by a deep sulcus bearing vascular foramina: absent (0); present (1).
39. Premaxilla, denticle morphology: one large conical denticle adjacent to interpremaxillary suture on each premaxilla (0); two large, rostrocaudally elongate denticles on each premaxilla (1); four or more conical denticles of similar size on each premaxilla (2); three rostrally projecting denticles that decrease in size laterally (3).
40. Premaxillary foramen located rostrally and ventrolaterally to the rostral margin of the external naris: absent (0); present (1).

41. Premaxillary accessory foramen entering rostrally through the outer (rostral) narial fossa, located rostral to the premaxillary foramen: absent (0); present, empties into a common chamber with the premaxillary foramen (1).
42. Premaxillary accessory narial fossa located rostral to the circumnarial depression: absent (0); present, separated from circumnarial depression by a rostrocaudally wide ridge (1).
43. Premaxillary additional accessory fossa located lateral to the rostral accessory fossa and rostrolateral to the circumnarial depression, parallel with the lateral border of the oral margin: absent (0); present (1).
44. Elongation of premaxillary caudodorsal process: the premaxillary caudodorsal process does not meet the caudoventral process caudally (0); elongate caudodorsal process that extends caudally to meet the caudoventral process, forming the caudal margin of the external naris (1).
45. Premaxilla, vertical groove on the caudolateral process rostral to the maxillary dorsal process that extends ventrally from a small lateral opening between the premaxillary caudal processes: absent (0); present (1).
46. Premaxilla, elongation of the caudolateral process in adults: short, the caudolateral process does not contact the lacrimal (0); the caudolateral process extends caudodorsally to end dorsal to the lacrimal or mediodorsal to the rostral end of the prefrontal (1); long, the caudoventral process extends to end medial to the dorsal region of the prefrontal (2); very long, the caudoventral process extends caudodorsal to the prefrontal (3).
47. Premaxilla, morphology of the caudal region of the caudolateral process of the adult premaxilla: mediolaterally compressed and triangular (0); dorsoventrally broad and directed caudally, or caudally and slightly dorsally (1); triangular and dorsoventrally expanded, laterally convex lobe, directed rostradorsally (2).
48. Premaxilla, external naris shape: bony external naris formed by premaxilla and nasal (0); naris defined entirely by premaxilla, naris elongate (1); naris defined entirely by premaxilla, naris lacrimiform in shape (2).
49. Premaxilla, dorsolateral flange at approximately mid-length of the mediolaterally compressed caudoventral process of the premaxilla: absent (0); present (1).

NASAL

50. Nasal, location of the nasal bone and nasal cavity in the adult skull: the nasal extends from the rostral region of the skull to the rostradorsal region of the snout with the nasal cavity rostromedial to the orbit (0); nasal retracted caudal to the rostrum, forming a large portion of a

- supracranial hollow crest (1); nasal retracted caudal to the rostrum and atrophied, forming only a small portion of the hollow nasal crest (2). (Prieto-Marquez, 2010, character 75, modified)
51. Nasal, morphology of the rostral end at the contact with the dorsal process of the premaxilla: long and wedge-shaped rostral process, gradually decreasing in width rostrally to a sharp point (0); hook-like process, it becomes abruptly deep near the rostral end and then wedges rostrally (1); long and subrectangular process, with slightly rounded corners (2); small rostral process of the nasal fits along the ventral edge of the premaxilla, the latter briefly overlapping the nasal (3): the nasal bifurcates to meet the premaxilla in a W-shaped interfingering suture, a long and finger-like process of the nasal has an extensive overlapping joint with the caudodorsal process of the premaxilla; and additional, more caudally located shorter process of the nasal abuts the premaxilla. (4).
 52. Nasal, morphology of the nasal contact with the caudodorsal region of the caudoventral premaxillary process at the caudal margin of the narial foramen: the nasal forms a subrectangular flange exposed dorsal to the premaxillary caudoventral process (0); the nasal forms a large hook-like rostroventral process, exposed dorsal to the premaxillary caudoventral process (1); the nasal forms a greatly shortened and dorsoventrally narrow hook-like rostroventral process, exposed dorsal to the premaxillary caudoventral process (2).
 53. Nasal, location of the rostral end of the dorsal process relative to the rostral margin of the external naris: the rostral end of the rostrodorsal process of the nasal does not reach the rostral margin of the narial foramen (0); the rostral end of the rostrodorsal process of the nasal reaches the rostral margin of the narial foramen (1).
 54. Nasal arch: absent, dorsal border of the rostral process of nasal at about the same level as the caudal plate (0); present, summit located dorsal to the caudal margin of the narial foramen (1); present, summit located caudodorsal to the caudal margin of the narial foramen (2).

MAXILLA

55. Maxilla, rostrodorsal process: absent (0); present (1); absent, but the rostral end of the maxilla forms a ventrally sloping rostrodorsal shelf that underlies the premaxilla (2).
56. Maxilla, direction of rostroventral process: rostrally directed (0); rostroventrally curved (1), pendant (2).
57. Maxilla, shape of dorsal process: rostrocaudally narrow and hook-like (0); rostrocaudally wider than tall and subtriangular (1); dorsoventrally taller than wide and triangular, with a peaked and caudally inclined apex (2); subrectangular, presence of a rostrodorsal flange (3).

58. Maxilla, jugal process morphology: dorsally concave, rostr dorsally to caudoventrally inclined shelf, scarf contact with jugal (0); sinuous shelf, scarf contact with jugal (1); caudolaterally projecting jugal process, “finger-in-recess” contact with jugal (2); dorsolaterally-facing joint surface for the jugal with a caudolaterally directed corner (3); laterally-facing subtriangular joint surface that is more laterally than dorsally-facing, with a lateroventrally-directed pointed corner that is located adjacent and slightly dorsal to the proximal end of the lateral ridge of the ectopterygoid shelf (4); dorsally elevated jugal joint (distance between the ventral margin of the jugal joint and ectopterygoid shelf nearly equal to depth of the caudal segment of the maxilla), caudal margin of the joint flush with the caudal margin of the rostr dorsally eminence of the lateral side of the maxilla.
59. Maxilla, shape of antorbital fossa in lateral view: large triangular opening that occupies most of lateral surface of ascending process (0); large oval or circular opening that occupies most of lateral surface of ascending process (1) rostr caudally elongate, elliptical depression restricted to caudal half of ascending process (2); small semicircular depression restricted to caudal margin of ascending process (3); antorbital fossa not visible in lateral view (4).
60. Maxilla, arrangement of maxillary foramina ventral and rostral to the jugal articulation (excluding large rostr dorsally or rostrolateral foramen): positioned rostr caudally and scattered throughout the lateral side of the maxilla (0); forming either a row or cluster that is oriented rostr dorsally (1).
61. Maxilla, number of maxillary foramina ventral and rostral to the jugal articulation (excluding large rostr dorsally or rostrolateral foramen): seven or more (0); six or less (1).
62. Maxilla, large rostral maxillary foramen: opening on the rostrolateral body of the maxilla, within the rostral half of the rostr dorsally margin of the element, and exposed in lateral view (0); opening on the rostrolateral body of the maxilla, within the dorsal half of the rostr dorsally margin of the element, and exposed in lateral view (1); opening on the dorsal surface of the maxilla along the maxilla-premaxilla contact, not exposed laterally (2).
63. Maxilla, length of the ectopterygoid shelf relative to the total rostr caudal length of the alveolar margin of the maxilla: ratio less than 0.25 (0); ratio greater than 0.25 and up to 0.35 (1); ratio greater than 0.35 (2).
64. Maxilla, slope of the ectopterygoid shelf, measured as angle between this and the rostr caudal axis of the caudal portion of the tooth row: steeply inclined caudoventrally, with an angle greater than 21° (0); slightly inclined (angle less than 20°) or nearly horizontal (1).
65. Maxilla, morphology of the lateral emargination of the ectopterygoid shelf: dorsoventrally thin ridge (0); faint or dorsoventrally thin rostrally, then abruptly becoming dorsoventrally thick

along the caudal segment of the margin (1); dorsoventrally thick continuous ridge, gradually thicker caudally than rostrally (2).

LACRIMAL

- 66. Lacrimal, concave ventral margin to form part of antorbital fenestra: present (0); absent (1).
- 67. Lacrimal, contact with nasal: present (0); absent (1).

JUGAL

- 68. Jugal, ectopterygoid articulation: large sub-triangular ectopterygoid facet on medial side of jugal (0); small vertical ectopterygoid facet (1); absent, palatine-jugal contact enhanced (2).
- 69. Jugal, dorsoventral expansion of the rostral process: dorsoventrally narrow and does not participate in the rostroventral margin of the orbital rim (0); caudodorsal margin of rostral process forming a small, rostrocaudally-oriented process forming little of the rostroventral margin of the orbit (1); dorsoventrally expanded, with a dorsally-oriented or slightly recurved caudodorsal process forming the rostroventral corner of the orbital rim (2).
- 70. Jugal, rostral spur on the rostral process: no individualized spur (0); present, wedge-shaped, elongated and sharply pointed, positioned at mid-distance along the dorsoventral depth of the rostral process (1); positioned within the dorsal half of the rostral process of the jugal; the dorsal margin of the apex forms a steeper angle with the horizontal than in state (2); reduced to a blunt convexity or nearly straight rostral margin (3).
- 71. Jugal, contribution of caudal ramus to ventral margin of infratemporal fenestra: partial, quadratojugal also forms part of margin (0); caudal ramus forms entire ventral margin of infraorbital fenestra (1).
- 72. Jugal, shape of free ventral margin caudal to maxillary and ectopterygoid contacts: sinuous, jugal dorsoventrally expanded ventral to infratemporal fenestra (0); sinuous with striated, caudally-directed flange that projects caudal to jugal-quadratojugal contact (1); angular, with prominent ventrally-directed flange ventral to infratemporal fenestra (2); dorsoventrally narrow and strap-like, with convex ventral margin and concave dorsal margin that are parallel (3).

QUADRATOJUGAL

- 73. Quadratojugal, quadratojugal foramen: present (0); absent (1).

QUADRATE

- 74. Quadrate, position of the jugal wing: close to the distal condyles (0); positioned well dorsal to the distal condyles (1).
- 75. Quadrate, quadratojugal notch in lateral wing: absent (0); semicircular (1); high and crescentic (2).
- 76. Quadrate, position of the quadratojugal notch along the dorsoventral height of the quadrate: the mid-point of the notch is located near the mid-height of the quadrate (0); the mid-point of the notch is located ventral to the mid-height of the quadrate (1).
- 77. Quadrate, paraquadrate foramen: absent, caudal margin of quadratojugal contacts entire rostral margin of quadrate along the contact surface (0); present, gap between portion of caudal margin of quadratojugal and rostral margin of quadrate (1).
- 78. Quadrate, shape of dorsal condyle: subtriangular, broad rostral margin and tapers to a point caudally (0); subrectangular (1); D-shaped, broadest along lateral profile (2).
- 79. Quadrate, morphology of the ventral surface: mediolaterally broad and rostrocaudally compressed, lateral condyle slightly larger than the medial one; the ventral surface of the lateral condyle is only slightly offset ventrally relative to the ventral surface of the medial condyle (0); subtriangular in ventral view, lateral condyle rostrocaudally expanded and much larger than the medial one; the ventral surface of the lateral condyle is well offset ventrally relative to the ventral surface of the medial condyle (1).
- 80. Level of jaw joint: level with tooth row, or weakly depressed ventrally (0); strongly depressed ventrally, more than 40% of the height of the quadrate is below the level of the maxilla (1).

PREFRONTAL

- 81. Prefrontal, morphology of nasal process: tapering, finger-like projection (0); dorsoventrally broad, mediolaterally compressed plate (1).
- 82. Prefrontal, dorsomedial margin of the prefrontal developed into a caudodorsally-oriented crest: absent (0); present, not extending caudal to the prefrontal-frontal articulation (1): present, the crest extends caudally over the dorsal surface of the frontal and above the prefrontal-postorbital articulation in lateral view in adults (2).
- 83. Prefrontal, inclusion in the circumnarial fossa: absent (0); present (1).

POSTORBITAL

84. Postorbital, presence of a dorsal promontorium on the rostral process in adults: absent (0); present (1).
85. Postorbital, central body rostrocaudally expanded, rostrally excavated and bulging laterally ('inflated'), constricting the dorsal region of the infratemporal fenestra: absent (0); present (1).
86. Postorbital, shape of caudal end of squamosal process that overlaps the lateral surface of the squamosal: tapers to a point (0); rounded (1); bifurcated (2).
87. Postorbital, neurovascular foramen above jugal process: absent (0); present (1).
88. Postorbital, caudal process expanded above the infratemporal fenestra: absent (0); present (1).
89. Postorbital, dorsal inflection of the prefrontal and squamosal rami resulting in a Y-shaped postorbital in lateral view: absent (0); present (1).

SQUAMOSAL

90. Squamosal, length of the precotyloid process: precotyloid process as long or longer than width of the quadrate cotylus (0); precotyloid process distinctly shorter than width of quadrate cotylus (1).
91. Squamosal, dorsoventral expansion of the caudolateral surface: unexpanded, shallowly exposed in caudal view (0); greatly expanded dorsomedially, forming a deep, near vertical, well-exposed face in caudal view (in adults) (1).
92. Squamosal, separation of the squamosals at the occipital margin of the skull roof: completely separated by the parietal (0); the squamosal approaches the sagittal plane of the skull, separated by a narrow band of parietal (1); extensive intersquamosal joint present at the midline, parietal completely excluded from the sagittal plane of the skull at that particular spot (in adults) (2).
93. Squamosal, rostromedial indenture of the medial ramus: present, medial ramus of the squamosal curves rostromedially, so that the back of the skull appears to be deeply indented rostrally when viewed dorsally (0); absent, medial ramus of the squamosal curved caudomedially (1); absent, medial ramus of the squamosal extends medially, forming a subsquared caudolateral border of the skull roof (2).

FRONTAL

94. Frontal, bifurcation of the rostromedial margin of the frontals at the sagittal plane of the skull roof, leaving a V-shaped space in between: absent (0); present (1).
95. Frontal, nasal articulation surface shaped into a rostroventrally-slopping and excavated platform, forming the floor of the hollow crest: absent (0); present, but relatively short, does not

- overhang the parietal in adults (1); present, extends caudodorsally to overhang the parietal, moderately inclined, median cleft present (2); present, overhangs the parietal, thickened and steeply inclined, median cleft absent (3).
96. Frontal, tongue-like process that projects caudodorsally to overhang the parietal in adults.
 97. Frontal, participation in dorsal orbital rim: present (0); absent (1)
 98. Frontal, upward doming dorsal to the braincase of subadult (and perhaps young adult) specimens: absent (0); present (1).
 99. Frontal, length/width ratio of the ectocranial surface: relatively elongated ectocranial surface, with a ratio greater than 0.8 (0); relatively short, with a ratio of 0.8 or less, but greater than 0.4 (1); greatly shortened ectocranial surface, with a ratio less than 0.4 (2).

PARIETAL

100. Parietal, maximum length/minimum width proportions of the adult parietal: very short, length/width ratio less than 1.40 (0); short, ratio between 1.40 and 2.35 (1); relatively long, ratio greater than 2.35 (2).
101. Parietal, orientation of the parietal midline crest: straight and level with the skull roof or slightly down-warped along its length (0); the sagittal crest deepens caudally and is strongly down-warped (1).
102. Parietal, rostral extension of the sagittal crest along the dorsal surface of the parietal: sagittal crest fades away or absent on the rostral third of the parietal (0); sagittal crest extends along the entire length of the parietal and remains sharp and well defined at the rostral region (1).

BASIOCCIPITAL

103. Basioccipital, orientation of occipital condyle: caudoventrally directed (0); caudally directed (1)
104. Basioccipital, length of constriction: relatively long and well-developed (0); relatively short and poorly developed (1).

BASISPHEOID

105. Basisphenoid, orientation of the basiptyergoid processes (measured as the angle between the ventral margins of both processes): angle less than 100° (0); angle of 100° or greater (1).
106. Basisphenoid, development of the alar process: moderately developed (0); very well developed, relatively large in size (1).

107. Basisphenoid, ventral transverse ridge between the basiptyergoid processes: absent or poorly developed (0); present, sharply defined ridge (1).

SUPRAOCCIPITAL

108. Supraoccipital, contribution to foramen magnum: present (0); absent, excluded by exoccipitals (1).
109. Supraoccipital, morphology of supraoccipital-exoccipital contact: straight suture that meets squamosal (0); ventrolateral corner of supraoccipital is inset into exoccipital so that supraoccipital is locked between exoccipitals (1).
110. Supraoccipital, inclination of caudal surface: caudal surface rostrally inclined (0); caudal surface nearly vertical (1).
111. Supraoccipital-exoccipital, caudal extension of the supraoccipital-exoccipital shelf above the foramen magnum: very short rostrocaudal length, approximately less than half the diameter of the foramen magnum (0); moderately long, approximately more than half but less than the diameter of the foramen magnum (1); very long, substantially longer (often twice or more) than the diameter of the foramen magnum (2).

EXOCCIPITAL-OPISTHOTIC

112. Exoccipital-Opisthotic, paroccipital process shape: dorsoventrally expanded distally (0); pendant (1).
113. Exoccipital-Opisthotic, paroccipital process orientation of pendant distal portion: straight and ventrally directed (0); curved rostrally (1).

REGIONAL CRANIAL CHARACTERS

114. External naris, position: confined to area immediately above oral margin of premaxilla (0); extends caudally so as to lie dorsal to maxilla (1).
115. Narial foramen, length: ratio between the length of the narial foramen and the distance between the rostroventral corner of the premaxilla and the rostroventral margin of the prefrontal: very short narial foramen, ratio up to 0.40 (0); moderately long narial foramen, ratio greater than 0.40 but less than 0.60 (1); elongated narial foramen, ratio between 0.60 and 0.65 (2). extremely long narial foramen, ratio greater than 0.65 (3).

116. Hollow nasal crest, enclosure of the nasal passages on lateral crest surface between the caudolateral process of the premaxilla and nasal: absent (0); premaxilla nasal-fontanellae persist into late ontogenetic stages (1); fontanellae completely closed in subadult individuals (2).
117. Caudal extent of the nasal passage dorsal and/or caudal to the orbit: absent, nasal passage restricted to the antorbital region of the skull (0); present (1).
118. Nasal vestibule morphology, folded into a S-loop in the enclosed premaxillary passages rostral to the dorsal process of the maxilla: absent (0); present (1).
119. Location of lateral diverticulum, relative to the common median chamber: absent (0); lateral (1); rostral (2); caudodorsal (3).
120. Communication between the external naris, the lateral diverticulum, and the common median chamber: absent (0); a tubular premaxillary passage extends caudodorsally from the bony naris to the lateral diverticulum that is then connected to the common median chamber (1); a tubular premaxillary passage connects directly from the bony naris to the common median chamber (2).
121. External naris, composition of the caudal margin: formed by the nasal dorsally and the premaxilla ventrally (0); formed entirely by the nasal (1); formed entirely by the premaxilla (2).
122. Circumnarial fossa (homologous to the lateral diverticulum inside hollow supracranial crests), caudodorsal extension: the fossa does not reach the caudal margin of the narial foramen and, thus, lacks a caudal margin (0); the fossa extends as far as to surround the caudal margin of the narial foramen, but does not reach the orbit (1); the fossa extends as far as the rostradorsal region of the orbit (2); the fossa extends beyond the orbit, caudodorsal to its caudal margin (3).
123. Circumnarial fossa, degree of excavation of the caudal region: lightly incised (0); deeply incised, but not invaginated in adults (1); deeply incised and invaginated in adults (2). Character treated as ordered.
124. Hollow supracranial crest, nasal forms a large, plate-like portion of the caudal external crest surface: absent (0); present (1).
125. Supracranial crest, general shape: absent (0); mediolaterally compressed arcuate protuberance, rostral or, in adults, dorsal to the level to the orbits (1); paddle-like and caudally (as well as slightly dorsally) directed solid blade of bone (2); mediolaterally narrow and paddle-like, extending above the skull roof (3); rostrally excavated and rostrally-facing protuberance (4); nasal fold that rises dorsally or caudodorsally to form a laterally excavated promontory (5); raised into a large vertical fan, formed by a solid plate-like extension of the premaxilla (“cockscorn”) above the nasal passages in the rostral region of the crest (6); long and tubular, caudodorsally directed beyond the occiput and slightly arched (7).
126. Hollow nasal crest, crest-snout angle along dorsal margin of premaxilla in lateral view: absent, the lateral profile of the snout is continuous with the lateral profile of the dorsal premaxillary

- margin of the crest (0); facial profile shallowly concave in lateral view, angle greater than 140° (1); angle between 110° and 140° (2); crest procumbent and rostrally inclined, angle less than 110° (3).
127. Palpebral (supraorbital) bone: present (0); absent (1).
128. Orbit, length/width proportions: nearly circular, approximately as wide as it is deep (0); elongated, dorsoventrally deeper than it is wide (1).
129. Infratemporal fenestra, location of dorsal margin relative to the orbital dorsal margin: below the level of the orbital margin (0); approximately at the same level as the orbital margin (1); above the level of the orbital margin (2).
130. Infratemporal fenestra, shape: dorsal infratemporal margin wider than or approximately as wide as the ventral margin (0); dorsal infratemporal margin narrower than ventral margin (1); postorbital process and caudal blade sub-parallel and ventral infratemporal margin consequently constricted (2).

DENTAL CHARACTERS

131. Premaxillary teeth: present (0); absent (1).
132. Premaxillary teeth, striations: present (0); absent (1).
133. Dentary/maxillary teeth, at least moderately developed labiolingual expansion of crown ('cingulum') on maxillary/dentary teeth: present (0); absent (1).
134. Dentary teeth, roots: not cemented (0), partially cemented (1); rugose, angular-sided roots (2). Character treated as ordered.
135. Dentary teeth, intercrown spaces: present (0); absent (1).
136. Dentary teeth, morphology of marginal denticles: tongue-shaped with smooth edges (0); tongue-shaped with mammillated edges (1); absent or reduced to small papillae along the apical half of the crown (2).
137. Minimum number of functional teeth per alveoli at mid-length of dental battery: two (0); three (1); four (2); five or more (3).
138. Dentary teeth, number of teeth per tooth position forming part of occlusal plane: one (0); two (1); three (2).
139. Dentary teeth, shape of crown in lingual view: apicobasally short and subtriangular (0); oblong, shield-like surface, height/ width ratio < 3.0 (1); mesiodistally narrow and diamond-shaped, height/ width ratio > 3.0 (2).
140. Dentary teeth, position of primary ridge: mesially offset (0); distally offset (1); no offset, primary ridge divides the lingual side of the crown into equal halves (2).

141. Dentary teeth, multiple accessory ridges on either side of the primary ridge: multiple separate faint accessory ridges (0); multiple evenly-spaced accessory ridges on either side such that entire lingual surface is corrugated (1); accessory ridges, when present, reduced to secondary and tertiary ridges (2).
142. Dentary teeth, development of the secondary ridge mesial to primary ridge: well developed, reaches the apex of the crown (0); faintly developed, does not reach the apex of the crown, absent on some teeth (1); absent or occasional (2). Character treated as ordered.
143. Dentary teeth, development of tertiary ridges mesial or distal to primary ridge: at least one tertiary ridge reaches the apex of the crown (0); faintly developed, do not reach the apex of the crown (1); absent (2). Character treated as ordered.
144. Dentary teeth, shape of the primary ridge: straight in all teeth (0); straight for some crowns and sinuous for others. (1).
145. Dentary teeth, distal shelf at the base of the crown: absent (0); well-developed but smooth (1); well developed and mammillated (2).
146. Dentary teeth, distribution of the enamel: present both labially and lingually (0); only present lingually (1). (v, 2010, character 14, modified).
147. Dentary teeth, maximum number of tooth positions in the dental battery: 30 or less (0); 31–42 (1); more than 42 (2). Character treated as ordered.
148. Maxillary teeth, number of teeth per tooth position forming part of occlusal plane: one (0); one tooth for most of the dental battery, but sporadically two (1); two throughout most of the dental battery (2).
149. Maxillary teeth, prominent primary ridge: absent (0); present (1).
150. Maxillary teeth, height/width ratio at center of tooth row: less than 2.4 (0); at least 2.5 (1).
151. Maxillary teeth, number and morphology of ridges on labial surface of crown: one primary ridge with multiple parallel accessory ridges on either side (0); multiple ridges of similar size, such that primary ridge cannot be distinguished (1); primary ridge and only mesial accessory ridges (2); primary ridge only (3).
152. Maxillary teeth, primary ridge position and morphology: distally offset (0); no offset, primary ridge divides the labial side of the crown into equal halves (1).
153. Maxillary teeth, maximum number of tooth positions in the maxillary dental battery: up to 32 tooth positions (0); from 33 to 44 tooth positions (1); 45 or more tooth positions (2). (Character treated as ordered).

VERTEBRAE

154. Axis, morphology of neural spine in lateral view: caudodorsally sloping process (0); dorsally expanded process (1).
155. Cervical vertebrae, opisthocoely of centra: amphiplatyan or slightly (0); deeply opisthocoelous, hemispherical cranial face protrudes beyond ventral and dorsal surfaces of centrum and has a smooth, rounded surface (1).
156. Cervical vertebrae, development of the postzygapophyseal processes of cranial and middle cervical vertebrae: relatively low and relatively short, less than three times the rostrocaudal breadth of the neural arch (0); relatively high and relatively long, three times or more longer than the breadth of the neural arch (1).
157. Well-developed epiphysis on the third cervical: absent (0); present (1).
158. Cervical vertebrae, number: 11 or less (0); 12 or more (1).
159. Posterior dorsal and sacral vertebrae, height of the neural spine relative to that of the centrum (in adults): relatively low neural spine, ratio up to 3.25 (0); high neural spine, ratio greater than 3.25.
160. Sacral vertebrae, minimum count of co-ossified vertebrae in the sacral region (including single dorsal and caudal contributions: seven or fewer (0); eight or more (1).
161. Caudal vertebrae, chevron length relative to neural spine length on the proximal half of the tail: chevrons longer than neural spines (0); chevrons shorter than or nearly as long as neural spines (1).
162. Caudal vertebrae, chevrons, shape in lateral view: craniocaudally narrow (0); subtriangular (1); L-shaped (2).
163. Ossified epaxial tendons, extension: do not extend onto cervical vertebrae (0); extend on cervical vertebrae (1).
164. Ossified epaxial tendons, arrangement along dorsal, sacral, and caudal vertebrae: longitudinally arranged (0); double-layered lattice (1).
165. Ossified hypaxial tendons along the caudal chevrons: present (0); absent (1).

STERNAL

166. Sternal, caudolateral process: absent (0); present, slightly shorter than or as long as the craniomedial plate (1); caudolateral process longer than the craniomedial plate (2).
167. Mineralized intercostal plates: present (0); absent (1).
168. Ossified sternal ribs: present (0); absent (1).

CORACOID

169. Coracoid, ratio between the length of the lateral margin of the facet for the scapular articulation and the length of the lateral margin of the glenoid: slightly longer scapular facet, ratio greater than 1 and up to 1.30 (0); glenoid longer than the scapular facet, with a ratio up to 1 (1).
170. Coracoid, angle between the lateral margins of the facet for scapular articulation and the glenoid: angle greater than 115° (0); angle up to 115° (1).
171. Coracoid, morphology of the craniomedial margin: convex or straight, associated to a moderate development and slightly projected biceps tubercle (0); concave, associated to a relatively large and lateroventrally projected biceps tubercle (1).
172. Coracoid, orientation and development of the ventral hook-like process, measured as the ratio between the dorsoventral depth and the breadth of the process: ventrally directed and relatively short, ratio less than 0.65 (0); recurved, so that the process is caudoventrally directed, and relatively long, ratio more than 0.65 (1).

SCAPULA

173. Scapula, dorsal margin of the scapular shaft: straight (0); curved, dorsally convex (1).
174. Scapula, expansion of caudal end: gently convex expansion along caudodorsal margin, caudoventral margin tapers into hook-like flange (0); caudal end paddle-shaped, dorsal and ventral margins of scapula diverge towards caudal end (1); caudal margin of scapula straight, dorsal and ventral margins are parallel approaching caudal margin of scapula and meet caudal margin at nearly right angles (2).
175. Scapula, ratio between the craniocaudal length of the scapula (from the cranial end of the acromion process to the distal margin of the blade) and the dorsoventral depth of the cranial end (from the cranial end of the acromion process to the ventral apex of the glenoidal facet): relatively short scapula, ratio up to 4 (0); relatively long scapula, ratio greater than 4 (1).
176. Scapula, morphology and orientation of the pseudoacromial process: recurved, so that the cranial region is dorsally or craniodorsally directed (0); horizontal, occasionally with minor and subtle dorsal or ventral curvatures, so that the cranial region is cranially or mostly cranially directed (1).
177. Scapula, development of the deltoid ridge: dorsoventrally narrow convexity limited to the proximal region of the scapula, near the pseudoacromial process from which it develops, with a poorly demarcated ventral margin (0); dorsoventrally deep and craniocaudally long, with a well demarcated ventral margin (1).

178. Scapula, shape of acromion process in lateral view: subtriangular (0); cranial margin of process is convex (1); low, rounded protuberance (2); spike-like (3).

HUMERUS

179. Humerus, shape of the deltopectoral crest: distal margin rounded and merges gradually with the lateral margin of the humeral shaft (0); distal margin angular and merges abruptly with the lateral margin of the humeral shaft (1); deltopectoral crest weakly developed or absent (2).
180. Humerus, length of the deltopectoral crest (measured as the ratio between the proximodistal length of the crest and the proximodistal length of the humerus): proximodistally short crest, ratio less than 0.48 (0); ratio between 0.48 and 0.55 (1); very long crest, ratio greater than 0.55 (2).
181. Humerus, lateral expansion of the deltopectoral crest (measured as the ratio between the width of the humerus across the distal fourth of the deltopectoral crest and the width of the distal shaft at the point of maximum curvature): poorly expanded deltopectoral crest, ratio less than 1.65 (0); ratio between 1.65 and 1.90 (1); very expanded deltopectoral crest, ratio greater than 1.90 (2).

MANUS

182. Carpus, structure: fully ossified, with more than two small bones present, but not fused (0); carpals partially fused (1); carpals fused into two blocks (2); reduced to no more than two small carpals (3).
183. Manus, digit I: present (0); absent (1).
184. Metacarpal I, size: only slightly shorter than metacarpal II, not fused with radiale (0); less than 50% of metacarpal II, fused with radiale (1); absent (2).
185. Manus, ungual of digit I, shape: claw-like (0); spike-like, but flattened (1); spike-like and conical (2); absent (3).
186. Manus, arrangement of metacarpals II-IV: spreading (0); closely appressed (1).
187. Manus, unguals of digits II and III, shape: claw-like (0); flattened, twisted and hoof-like (1).
188. Manus, digit III, number of phalanges: four (0); three (1).
189. Manus, digit V: short, two phalanges (0); elongated, 3 or 4 phalanges (1); lost (2).

ILIUM

190. Ilium, angle of ventral deflection of the preacetabular process: angle greater than 150° (0); angle of 150° or less (1).
191. Ilium, preacetabular process, twisting along its length such that the dorsal surface of the ilium becomes the lateral surface of the cranial end of the process: absent (0); present (1).
192. Ilium, morphology of dorsal margin of postacetabular process dorsal to ischial peduncle: smooth surface (0); mediolaterally thickened dorsal margin compared to dorsal margin above pubic peduncle (1); thickened and laterally-bulging everted rim along dorsal margin (2); laterally-projecting, non-pendant shelf continuous with dorsal margin of ilium (3); pendant supraacetabular process continuous with dorsal margin of ilium (4).
193. Ilium, position of the ventralmost margin of the supraacetabular process relative to the caudoventral margin of the lateral ridge of caudal protuberance of the ischial peduncle: apex located caudodorsally (0); apex located craniodorsally (1).
194. Ilium, symmetry of the lateral profile of the supraacetabular process: asymmetrical, with a caudally skewed lateral profile (0); symmetrical or with a slightly caudally skewed profile (1).
195. Ilium, morphology of the lateroventral margin of the supraacetabular process: craniocaudally sinuous (0); widely arched (1); U-or V- shaped (2); subrectangular, with a shallow notch that divides the ventral margin in two poorly demarcated lobes (3).
196. Ilium, morphology of the pubic peduncle: relatively large and dorsoventrally deep (longer than wide), subconical, with a proximal region that is only slightly craniocaudally wider than the distal end of the process (0); relatively shorter (wider than or as wide as long) and triangular, with a proximal region that is much craniocaudally wider than the distal end (1).
197. Ilium, morphology of the ischial peduncle: formed by a single and large, oval ventral protrusion (0); composed of a large and oval ventral protrusion and by a smaller, caudodorsally located prominence emerging from the caudodorsal ridge (1); formed by two protrusions of similar size, the caudalmost one located slightly caudodorsally (2). (Prieto-Marquez, 2010, character 242).
198. Ilium, brevis shelf at the base of the postacetabular process: present but narrow (0); very broad and expanding in width towards its posterior margin such that it appears triangular in dorsal or ventral view (1); absent (2).
199. Ilium, postacetabular process, shape in lateral view: rounded with break in slope along dorsal margin, parallel dorsal and ventral margins (0); the ventral margin converges caudodorsally to meet the horizontal dorsal margin, forming a tapering caudal end and producing a triangular lateral profile of the process (1); the dorsal margin converges caudoventrally to meet the subhorizontal ventral margin, forming an elliptical lateral profile of the process (2); dorsal and ventral margins parallel or slightly convergent, forming a distinct (rectangular or subcircular),

caudodorsally-oriented caudal margin (3); sub-triangular, the dorsal and ventral margins converge to a blunt point (4).

200. Ilium, orientation of the dorsal margin of the postacetabular process relative to the acetabular margin: horizontal dorsal margin, parallel or nearly parallel to the acetabular margin (0); caudodorsally oriented dorsal margin, rising dorsally relative to acetabular margin (1); caudoventrally oriented dorsal margin (2).

PUBIS

201. Pubis, prepubic process proportion: rod-shaped, wider transversely than dorsoventrally (0); transversely flattened (1).
202. Pubis, cranial expansion of cranial pubic process: absent, dorsal and ventral margins parallel (0); present, dorsal and ventral margins diverge distally (1).
203. Pubis, orientation of the dorsoventral expansion of the prepubic process: the dorsal region of the expansion is more expanded than the ventral region, so that distally the process is dorsally directed (0); the ventral region is more expanded than the dorsal region, so that the distal expansion is ventrally directed (1).
204. Pubis, geometry of the dorsoventral expansion of the prepubic process (in lateral or medial views): circular to oval expansion, extensive and convex ventral margin (0); subsquared distal dorsal margin, expansion dorsoventrally taller than cranioventrally long, very pronounced proximal dorsal concavity and nearly straight distal ventral margin (1); ellipsoidal expansion craniocaudally longer than dorsoventrally tall, well-pronounced concavities of the dorsal and ventral proximal margins (2); oval expansion, dorsoventrally taller than craniocaudally long, well-pronounced concave profiles of dorsal and ventral proximal margins (3); rectangular, craniocaudally longer than dorsoventrally tall, nearly straight profiles of the dorsal and ventral proximal margins (4).
205. Pubis, craniocaudal length of the proximal constriction of the prepubic process relative to length of the dorsoventral expansion: constriction and distal expansion have approximately the same length (0); constriction shorter than the dorsoventral expansion, which begins at the proximal region of the process (1); constriction longer than the dorsoventral expansion, which is restricted to the distal region of the process (2).
206. Pubis, relative position of maximum concavity of the dorsal and ventral margins of the prepubic process: maximum ventral concavity achieved adjacent to the proximal region of the prepubic process, maximum dorsal concavity located further distally (0); maximum ventral concavity located ventral to or slightly caudal to the maximum dorsal concavity (1).

- 207. Pubis, obturator process on postpubic ramus: absent (0), or present (1).
- 208. Pubis, caudal pubic process: approximately equal in length to ischium (0); shorter than ischium (1).

ISCHIUM

- 209. Ischium, elongation of the iliac peduncle (ratio between the proximodistal length and the craniocaudal width of the distal margin): relatively short peduncle, ratio less than 1.85 (0); relatively long peduncle, ratio greater than 1.85 (1).
- 210. Ischium, relative orientation of the acetabular and caudodorsal margins of the iliac peduncle: margins are either parallel or slightly convergent relative to each other (correlated with a greater expansion of the craniodorsal corner of the peduncle) (0); margins become slightly to greatly divergent near the proximal region of the peduncle (1).
- 211. Ischium, orientation of the craniocaudal axis of the pubic peduncle (perpendicular to its articular margin) relative to the ischial shaft: ventrally inclined, angle up to 130° (0); slightly inclined ventrally or parallel, angle greater than 130° (1).
- 212. Ischium, length/width proportions of the pubic peduncle: approximately as long or slightly longer proximodistally as the distal articular surface is dorsoventrally wide (0); proximodistally shorter than the dorsoventral width of the distal articular surface (1).
- 213. Ischium, position of obturator process: positioned beyond the proximal 33% of the length of the ischium (0); positioned within the proximal 33% (1); absent (2).
- 214. Ischium, morphology of shaft: curved caudally (0); curved cranially (1); straight (2).
- 215. Ischium, morphology of distal end: rounded expansion (0); cranially expanded boot (1); bluntly truncated (2).

FEMUR

- 216. Femur, curvature of shaft: distal half of shaft curved caudally (0); distal half of shaft straight (1).
- 217. Femur, deep cleft separating the greater and lesser trochanters on the proximal end: absent (0); present (1).
- 218. Femur, groove on caudal aspect of femoral head: present (0); absent (1).
- 219. Femur, morphology of fourth trochanter: pendant (0); broad, triangular, and ending in a caudally, and slightly ventrally, directed point (1); curved, laterally compressed eminence (2).
- 220. Femur, location of fourth trochanter: arises on proximal half of femoral shaft (0); arises at midshaft of femur (1).

- 221. Femur, location of insertion scar of *M. caudifemoralis longus*: extends from fourth trochanter onto medial surface of femoral shaft (0); widely separated from fourth trochanter, restricted to medial surface of femoral shaft (1).
- 222. Femur, intercondylar extensor groove: absent (0); broad, shallow, V-shaped, edges of groove meet at greater than 90 degrees to one another (1); tight, deep, V-shaped, edges of groove meet at less than 90 degrees (2); deep, U-shaped, partially enclosed by expansion of medial and lateral condyles (3); canal fully enclosed by fusion of lateral and medial condyles (4).
- 223. Femur, intercondylar flexor groove: completely open, U-shaped trough (0); partially closed by lateral inflation of medial condyle (1).
- 224. Lateral condyle of distal femur, position and size in ventral view: positioned relatively laterally, and slightly narrower in width than the medial condyle (0); strongly inset medially, reduced in width relative to medial condyle (1)

TIBIA

- 225. Tibia, cnemial crest: restricted to proximal head of tibia (0); extend along proximal part of diaphysis (1).

ASTRAGALUS

- 226. Astragalus, development of the medial platform: it extends medially to completely underlie the medial malleolus of the tibia (0); short, wedges laterally, underlying only part of the medial malleolus of the tibia (1).

PES

- 227. Pes, pedal digit I, metatarsal I present, 2 phalanges (0); metatarsal I present, no phalanges (1); metatarsal and phalanges absent (2).
- 228. Metatarsals III and IV, proximal ends, deep posterolateral notch on MT III for the reception of a prominent process of MT IV: absent (0); present (1).
- 229. Pes, metatarsal V: present (0); absent (1).
- 230. Pes, prominent lip extending proximodorsally from dorsal margins of phalangeal proximal articulation facets: present (0); absent (1).

- #### 4. Matrix file:

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Hypacrosaurus_stebingeri

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Lambeosaurus_magnicristatus

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Gryposaurus_notabilis
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Gryposaurus_monumentensis
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Secernosaurus_koernerii
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Willinakaqe_salitralensis
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Rhinorex_condrupus
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Prosaurolophus_maximus
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Saurolophus_osborni
21?1122411?101012141111210011210122221210100020000221-
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Saurolophus_angustirostris
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Kundurosaurus_nagornyi
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Edmontosaurus_annectens
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Edmontosaurus_regalis
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Shantungosaurus_giganteus
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Ugrunaaluk_kuukpikensis
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Kritosaurus_navajovius
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Naashoibitosaurus_osborni

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Cariocecus_bucagii
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Comptonatus_chasei
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Brighstoneus_simmondsi
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????????????????0?0000010--0-
0010?1011?0112020010010200????10????????????????????????001000000101?????00001??01?1
1130?????????
proc /;
comments 0
;

5. Measurements:

L: left. R: right.

Skull length: 285 mm
Preorbital length: 175 mm
External naris (L): 45.7 mm
External naris (L): maximum height: 7.8 mm
Prenarial length of premaxilla: 45.3 mm
Orbital length: 40.3 mm
Orbital height: 42.2 mm
Height infratemporal fenestra: 54.9 mm
Length infratemporal fenestra: 14.5 mm
Quadrate (R): height: 108 mm
Dentary (L): length (from rostral tip to apex of coronoid process): 155 mm
Dentary (L): height (at mid-length of dentary ramus): 42 mm
Scapula (L): height (proximodistal): 275
Scapula (R): maximum width (craniocaudal) of proximal plate: 75 mm
Scapula (R): minimum width (craniocaudal) of blade: 34 mm
Scapula (R): maximum width (craniocaudal) of blade: 67.5 mm
Coracoid (R): mesio-lateral length : 50 mm
Coracoid (R): dorso-ventral length: 65 mm
Sternal (L): 118 mm
Sternal (R): width of proximal plate: 38.4 mm
Sternal (L): width of distal handle: 24.5 mm
Humerus length (R) : 192 mm
Humerus (L): mediolateral width of proximal end: 57.7 mm
Humerus (R): mediolateral width of distal end: 44 mm
Ulna (L): length: 162 mm
Ulna (L): craniocaudal height of proximal part: 33 mm
Ulna (L): craniocaudal height of distal part: 33 mm
Radius (R): length: 141 mm
Radius (R): craniocaudal height of distal part: 34.8 mm
Metacarpal II (L): length: 45 mm
Metacarpal II (L): width at distal end: 16 mm
Metacarpal III (L): length: 60 mm
Metacarpal III (L): width at proximal end: 16 mm
Metacarpal III (L): width at distal end: 15.4 mm
Metacarpal IV (L): length: 55.4 mm
Metacarpal IV (L): width at proximal end: 15.5 mm
Metacarpal IV (L): width at distal end: 12.2 mm
Metacarpal V (L): length: 24.8 mm
Metacarpal V (L): width at proximal end: 16.1 mm
Metacarpal V (L): width at proximal end: 16.1 mm
Digit I, ungual (R): length: 32.9 mm
Digit I, ungual (R): maximal width: 16 mm
Digit II, phalanx1 (L), length: 19.6 mm
Digit II, phalanx1 (L), width at distal end: 12.7 mm
Digit II, phalanx 2 (L), length: 9.1 mm

Digit II, phalanx 2 (R), width at distal end: 14.3 mm
Digit II, ungual (R): length: 24.5 mm
Digit II, ungual (R): maximal width : 18.2 mm
Digit III, phalanx 1 (R), length: 20 mm 15.4
Digit III, phalanx 1 (R), width at distal end: 32 mm 14.1
Digit III, phalanx 2 (R), length: 9 mm 8.5
Digit III, phalanx 2 (R), width at distal end: 16.5
Digit III, ungual (R): length: 56 mm 20.73
Digit III, ungual (R): maximal width: 41 mm 19.6
Digit IV, phalanx 1 (L), length: 15.1 mm
Digit IV, phalanx 1 (L), width at distal end: 15 mm
Digit IV, phalanx 2 (L), length: 6.2 mm
Digit IV, phalanx 2 (L), width at distal end: 9.7 mm
Digit IV, ungual (L): length: 6.7 mm
Digit IV, ungual (L): maximal width: 9 mm
Digit V, phalanx 1 (L), length: 24.4 mm
Digit V, phalanx 1 (L), width at distal end: 13.8 mm
Digit V, phalanx 2 (R), length: 9.7 mm
Digit V, phalanx 2 (R), width at distal end: 10.1 mm
Digit V, ungual (L): length: 7 mm
Digit V, ungual (L): maximal width: 7.6 mm

6. EDS measurements showing the material and location of the points analysed in Extended Data Table 1:

a. Spike Sp1a:

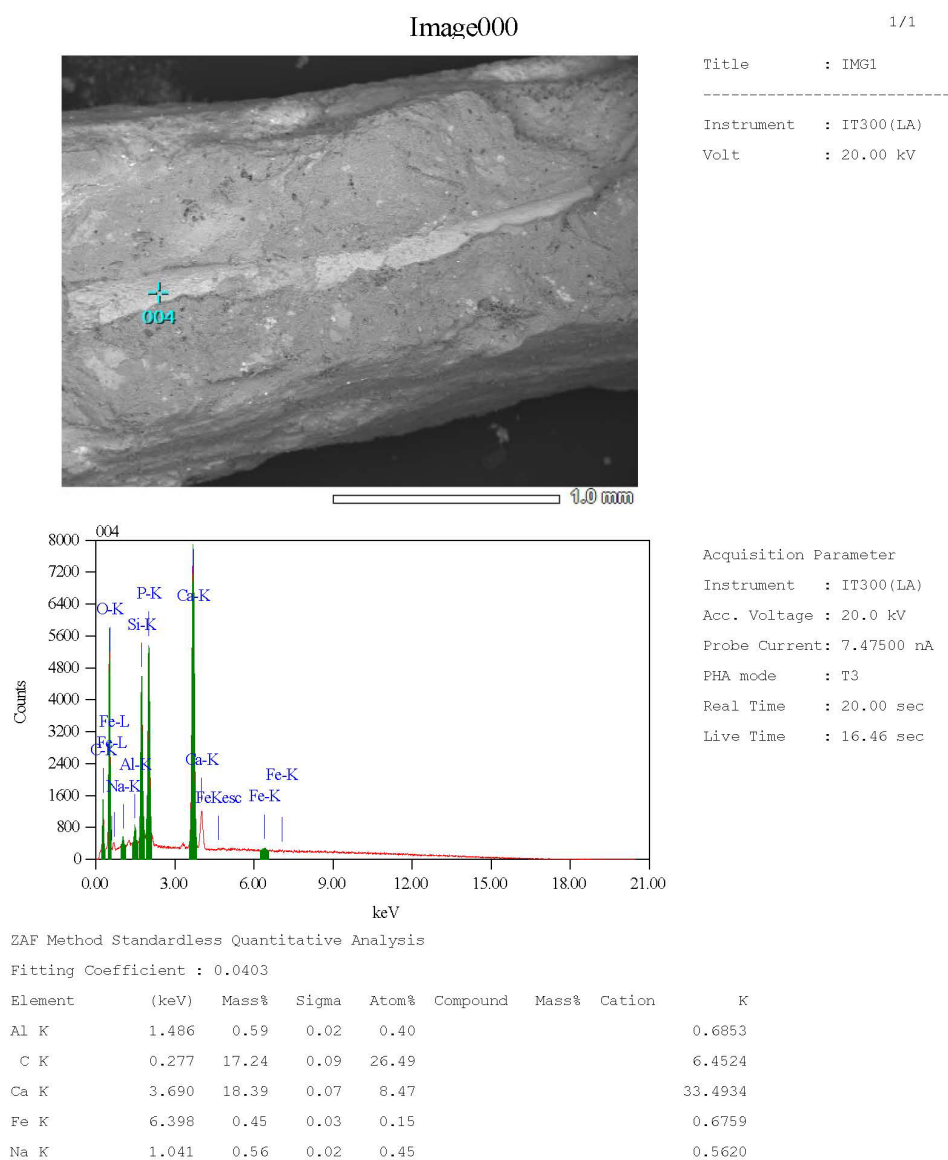
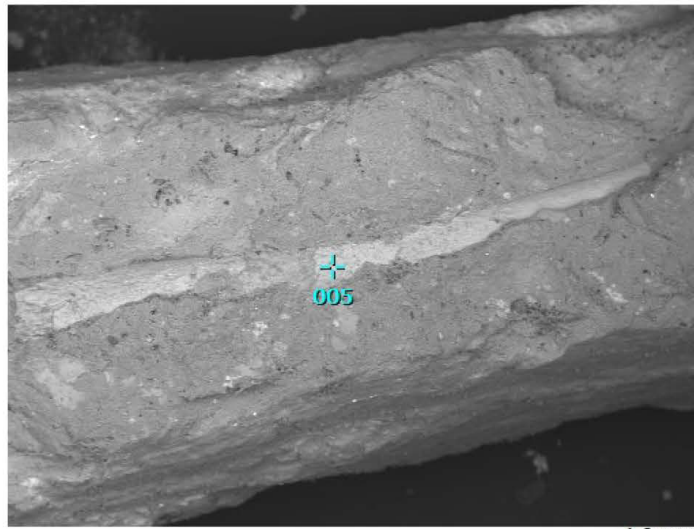


Image000

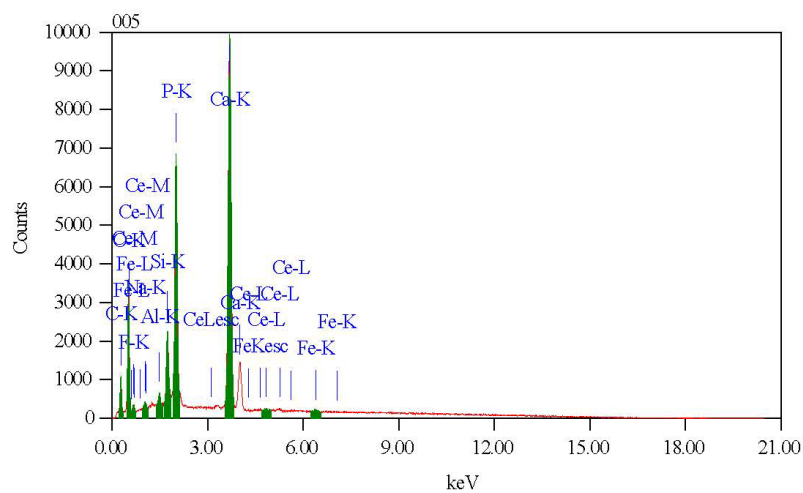
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 20.00 sec

Live Time : 16.88 sec

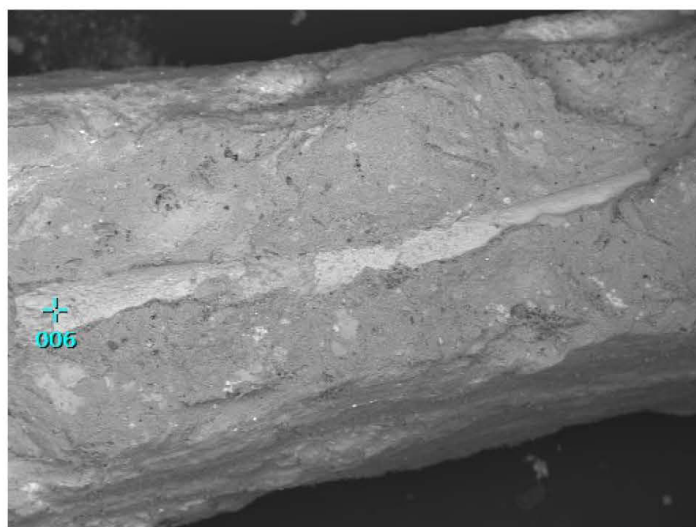
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0284

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.45	0.02	0.33				0.4762
C K	0.277	14.11	0.09	23.73				4.6604
Ca K	3.690	26.74	0.09	13.47				44.9597
Ce L	4.837	0.86	0.06	0.12				1.0682
F K	0.677	1.31	0.09	1.39				1.2440
Fe K	6.398	0.35	0.03	0.13				0.4732

Image000

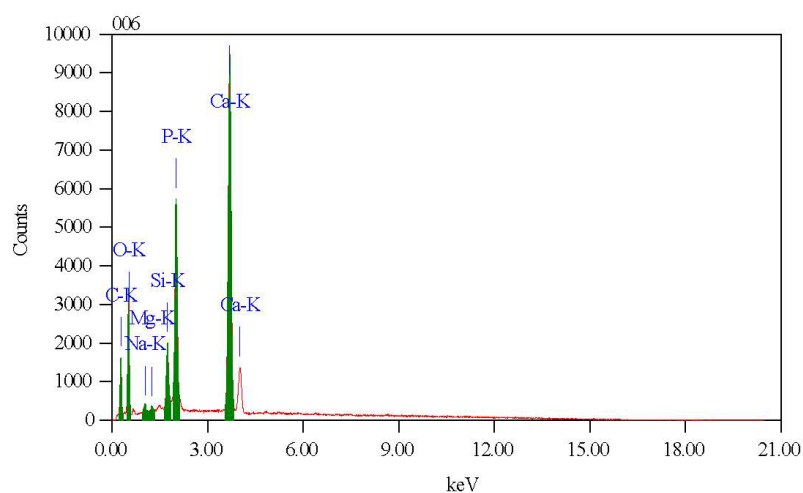
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 20.00 sec

Live Time : 17.25 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0308

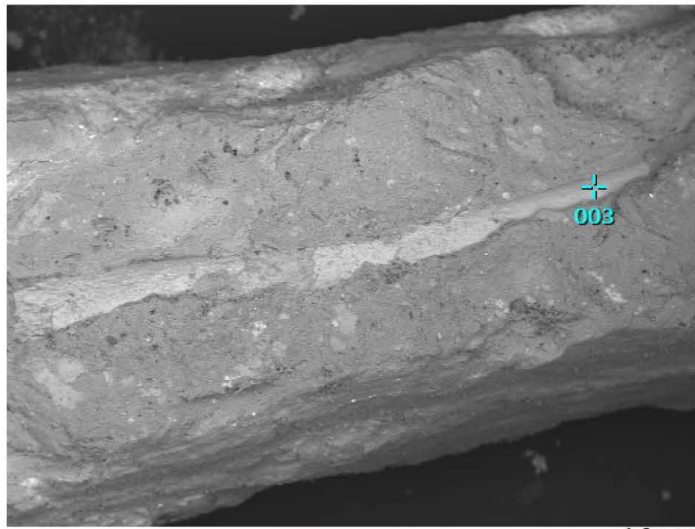
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	21.03	0.10	32.96				8.5265
Ca K	3.690	25.36	0.09	11.91				46.0713
Mg K	1.253	0.18	0.02	0.14				0.1693
Na K	1.041	0.52	0.02	0.43				0.5241
O K	0.525	39.07	0.23	45.99				21.6008

JED-2300 AnalysisStation

JEOL

Image000

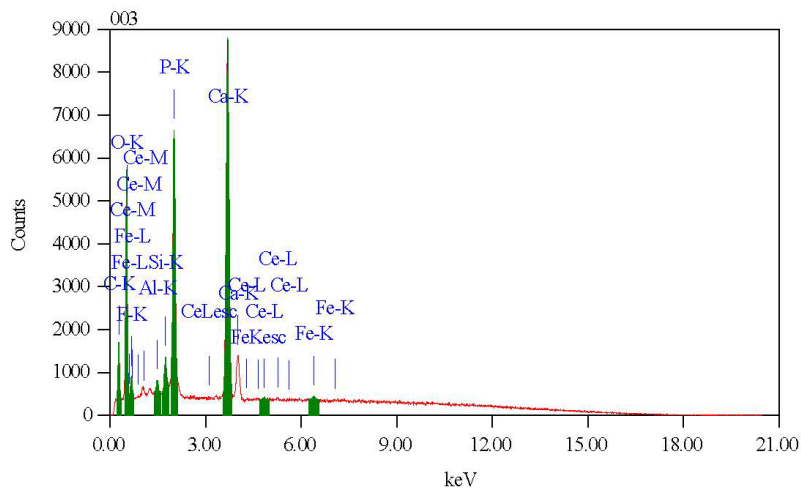
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 20.00 sec

Live Time : 15.05 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0409

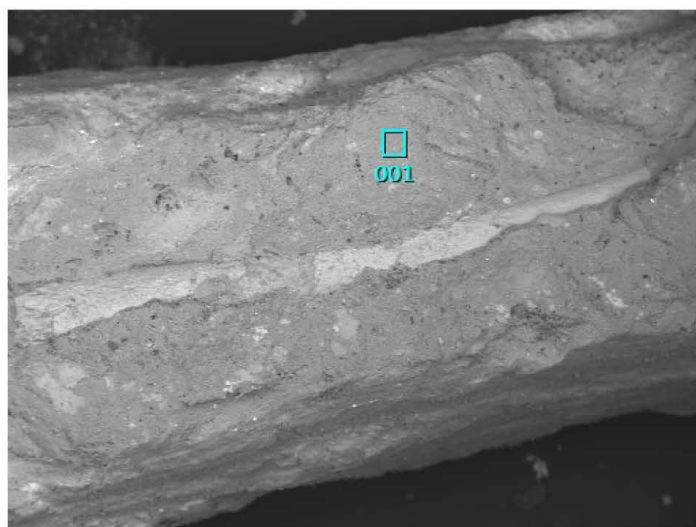
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.41	0.02	0.29				0.4534
C K	0.277	16.05	0.09	25.07				6.4580
Ca K	3.690	20.55	0.08	9.62				36.4281
Ce L	4.837	0.66	0.07	0.09				0.8675
F K	0.677	2.89	0.13	2.86				2.7683
Fe K	6.398	0.62	0.04	0.21				0.8867

JED-2300 AnalysisStation

JEOL

Image000

1/1

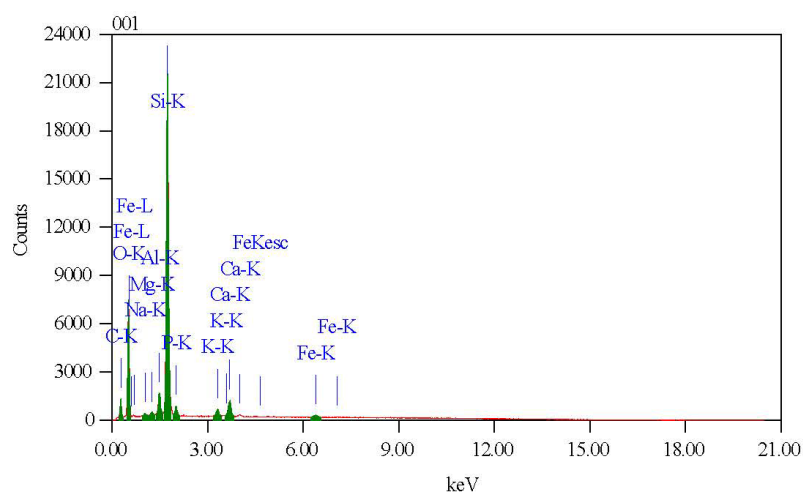


Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV

1.0 mm



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 20.00 sec

Live Time : 16.53 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0458

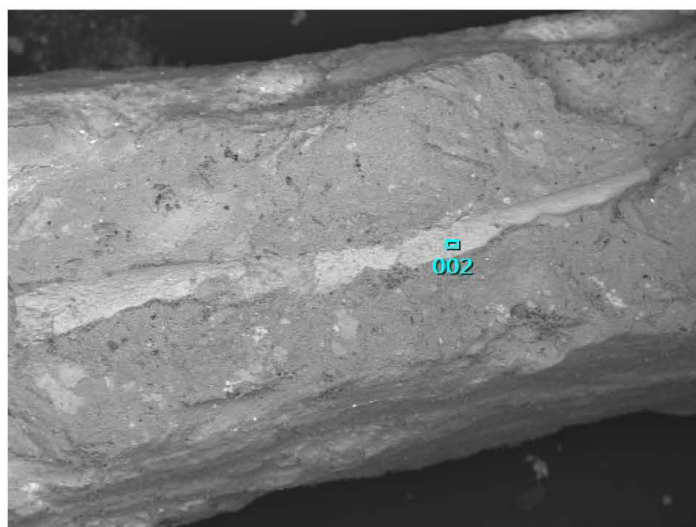
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	1.49	0.02	0.96				1.9707
C K	0.277	23.14	0.12	33.51				5.9791
Ca K	3.690	2.36	0.03	1.02				4.2654
Fe K	6.398	0.83	0.03	0.26				1.2888
K K	3.312	1.03	0.02	0.46				1.7540
Mg K	1.253	0.23	0.01	0.17				0.2531

JED-2300 AnalysisStation

JEOL

Image000

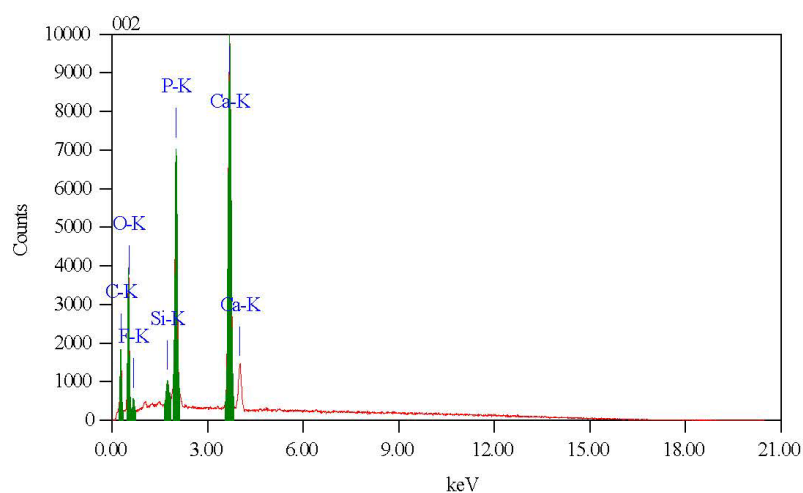
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 20.00 sec

Live Time : 16.33 sec

ZAF Method Standardless Quantitative Analysis

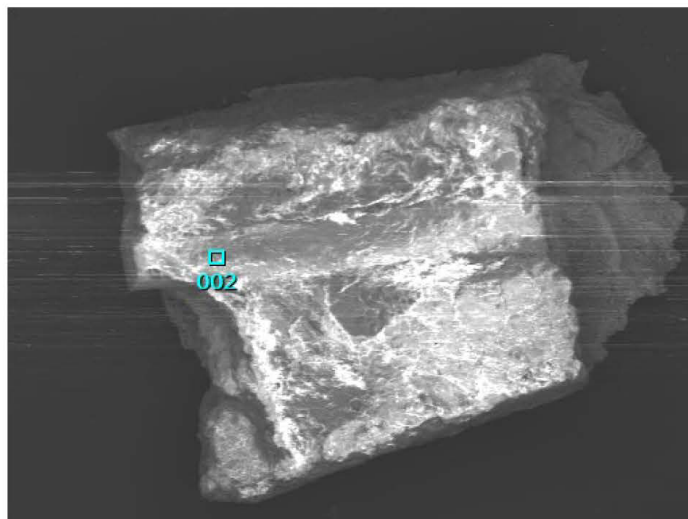
Fitting Coefficient : 0.0284

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	20.29	0.10	31.54				8.2930
Ca K	3.690	23.68	0.08	11.03				42.7011
F K	0.677	3.36	0.09	3.30				3.3349
O K	0.525	39.56	0.22	46.18				23.0272

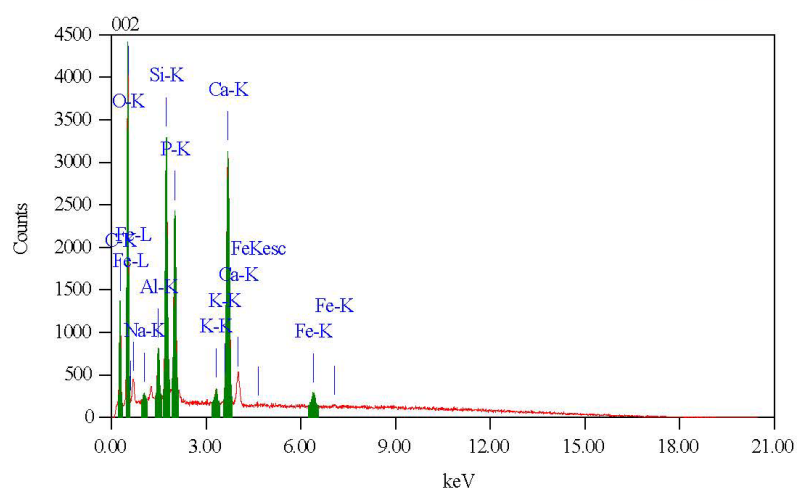
b. Spike Sp1b:

Image002

1/1



Title : IMG1
Instrument : IT300 (LA)
Volt : 20.00 kV

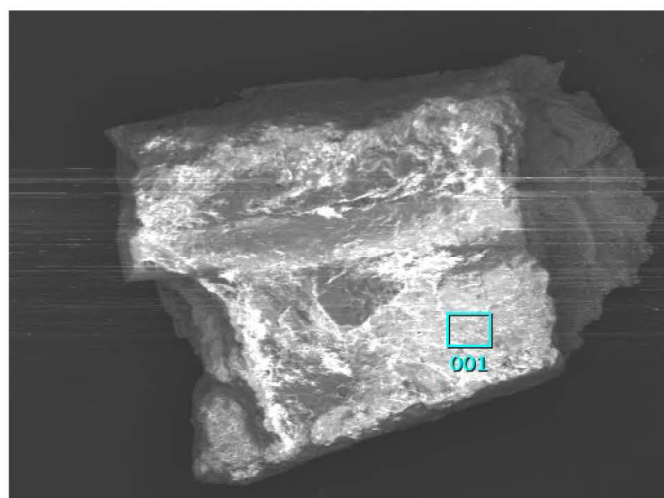


Acquisition Parameter
Instrument : IT300 (LA)
Acc. Voltage : 20.0 kV
Probe Current : 7.47500 nA
PHA mode : T3
Real Time : 20.00 sec
Live Time : 17.96 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0506

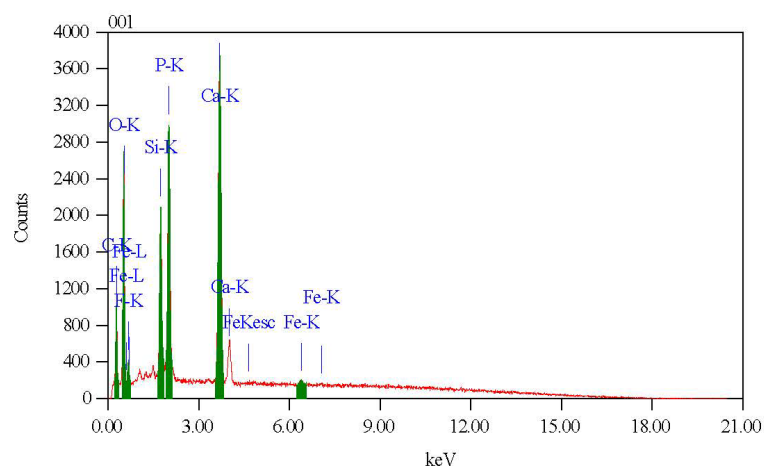
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	1.26	0.03	0.80				1.5718
C K	0.277	24.07	0.12	34.47				10.6505
Ca K	3.690	10.90	0.07	4.68				21.1536
Fe K	6.398	1.98	0.05	0.61				3.1513
K K	3.312	0.57	0.02	0.25				1.0758
Na K	1.041	0.37	0.03	0.28				0.3944



Title : IMG1

Instrument : IT300 (LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300 (LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 20.00 sec

Live Time : 17.86 sec

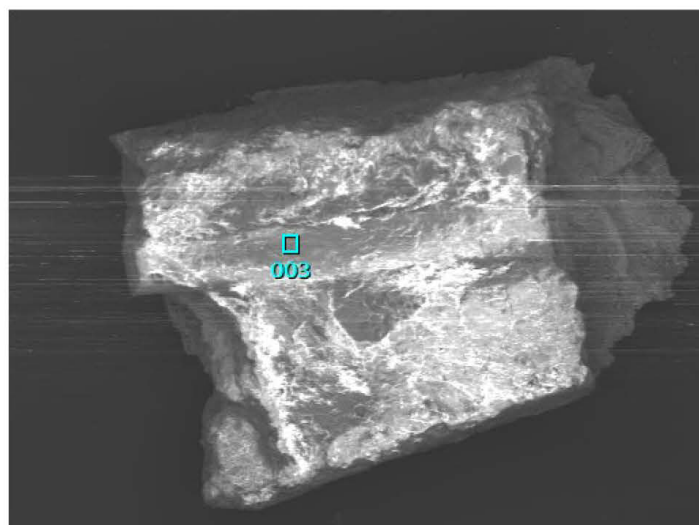
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0432

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	21.77	0.14	32.53				8.6751
Ca K	3.690	16.56	0.09	7.41				31.0466
F K	0.677	3.80	0.13	3.58				4.1019
Fe K	6.398	0.65	0.05	0.21				0.9898
O K	0.525	42.08	0.28	47.19				30.2585

Image002

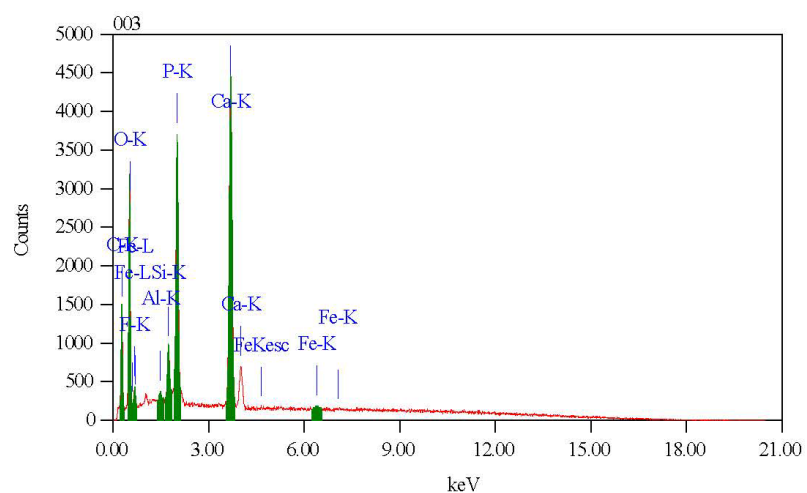
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

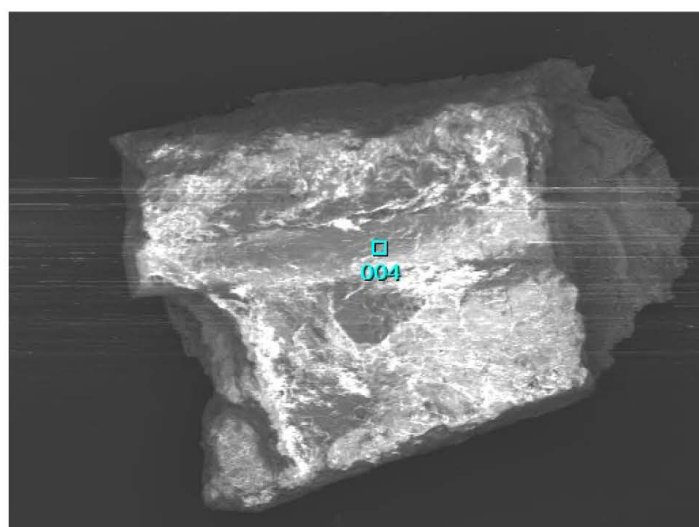
Real Time : 20.00 sec

Live Time : 17.81 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0412

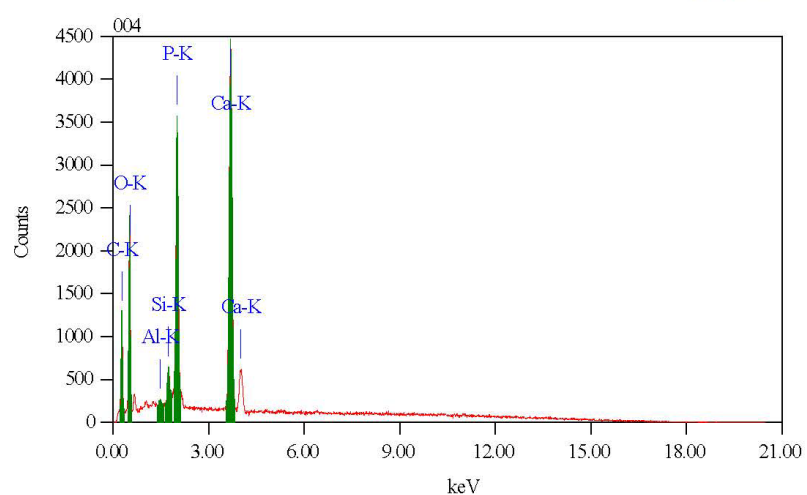
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.21	0.02	0.13				0.2534
C K	0.277	24.85	0.13	36.06				11.6941
Ca K	3.690	16.54	0.09	7.19				32.0174
F K	0.677	3.08	0.12	2.83				3.2916
Fe K	6.398	0.53	0.04	0.16				0.8235



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 20.00 sec

Live Time : 18.23 sec

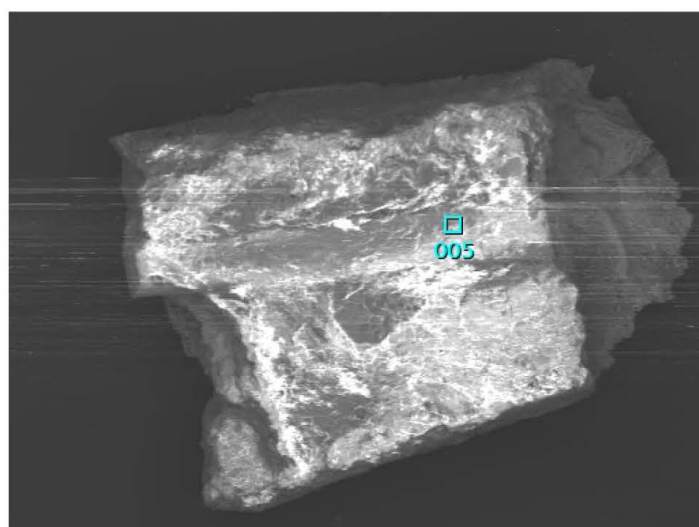
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0401

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.15	0.02	0.10				0.1923
C K	0.277	25.83	0.14	37.71				12.1018
Ca K	3.690	19.06	0.10	8.34				37.0990
O K	0.525	42.78	0.30	46.90				27.9871

Image002

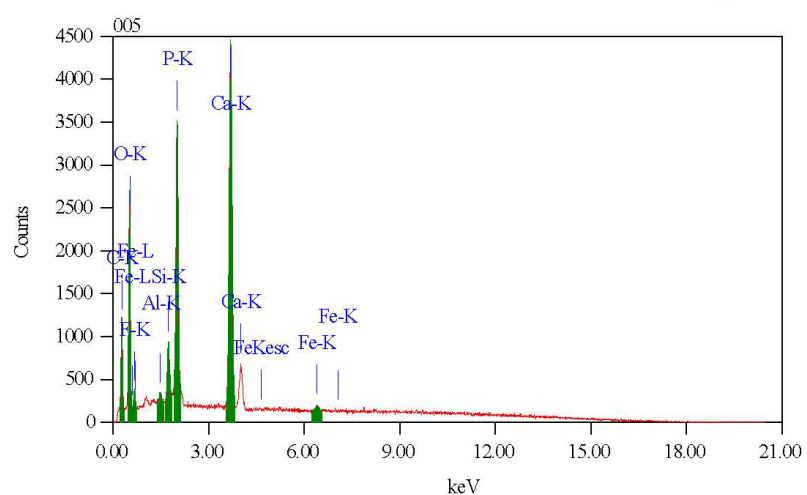
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 20.00 sec

Live Time : 17.95 sec

ZAF Method Standardless Quantitative Analysis

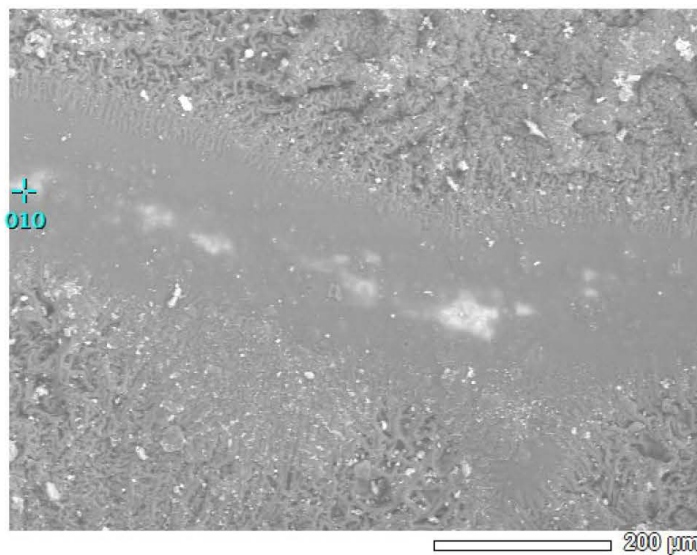
Fitting Coefficient : 0.0407

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.22	0.02	0.14				0.2615
C K	0.277	23.27	0.13	34.50				10.3445
Ca K	3.690	18.01	0.09	8.00				34.0991
F K	0.677	3.45	0.12	3.23				3.6436
Fe K	6.398	0.76	0.05	0.24				1.1659

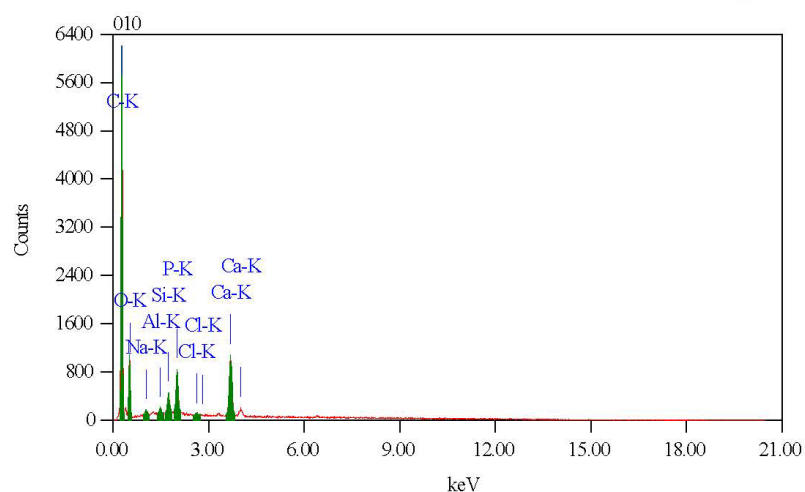
c. Spike Sp2a:

Image000

1/1



Title : IMG1
Instrument : IT300(LA)
Volt : 20.00 kV

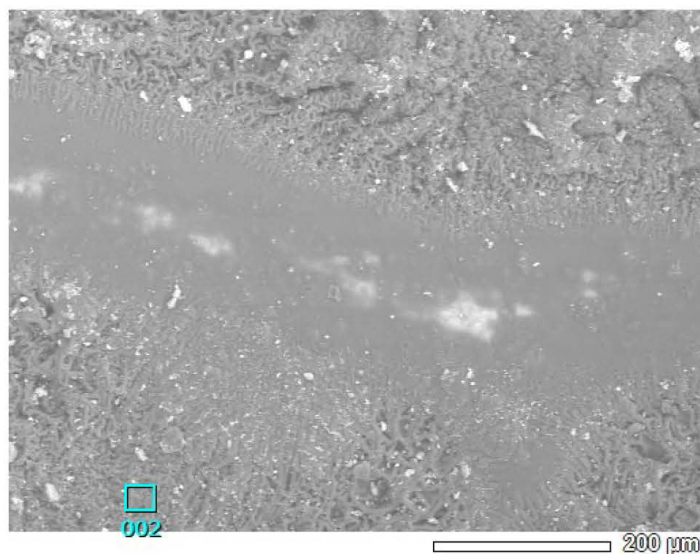


Acquisition Parameter
Instrument : IT300(LA)
Acc. Voltage : 20.0 kV
Probe Current: 7.47500 nA
PHA mode : T3
Real Time : 14.13 sec
Live Time : 13.34 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0455

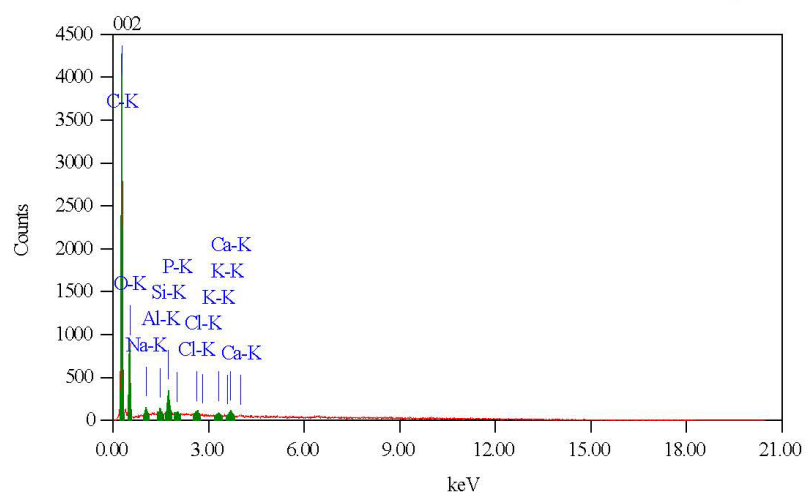
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.24	0.01	0.12				0.3374
C K	0.277	68.03	0.15	76.56				70.9861
Ca K	3.690	4.25	0.05	1.43				8.8925
Cl K	2.621	0.08	0.01	0.03				0.1582
Na K	1.041	0.34	0.02	0.20				0.4494



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

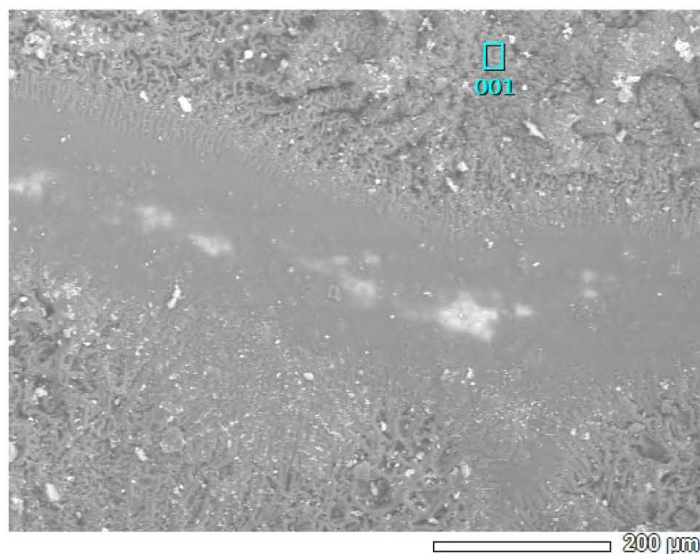
Real Time : 15.00 sec

Live Time : 14.51 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0600

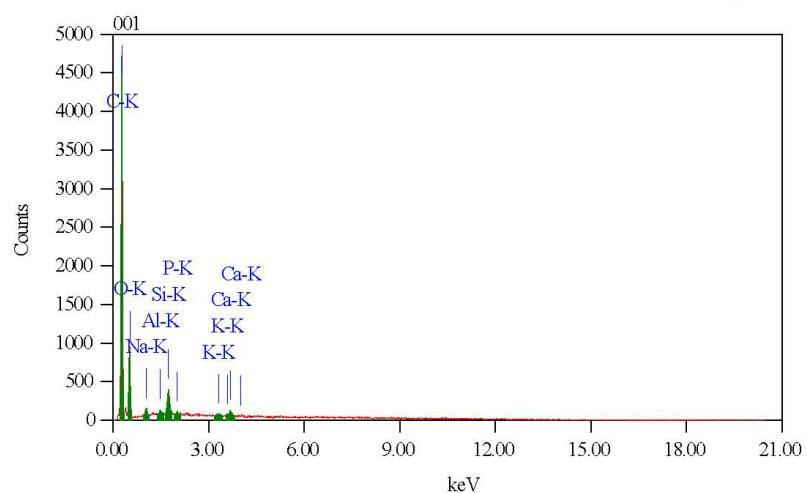
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.22	0.02	0.11				0.2990
C K	0.277	66.65	0.18	73.46				76.7089
Ca K	3.690	0.39	0.03	0.13				0.7907
Cl K	2.621	0.22	0.02	0.08				0.4347
K K	3.312	0.17	0.02	0.06				0.3321
Na K	1.041	0.68	0.04	0.39				0.8387



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 14.46 sec

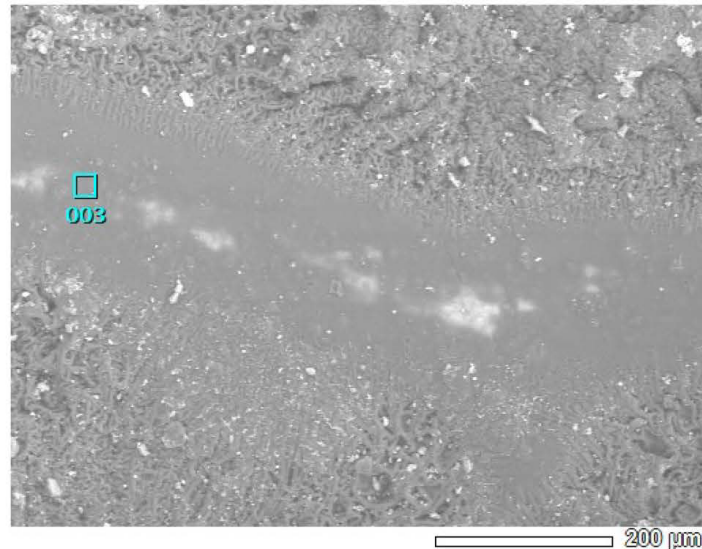
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0602

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.17	0.02	0.08				0.2274
C K	0.277	67.36	0.17	74.01				78.1542
Ca K	3.690	0.40	0.03	0.13				0.7898
K K	3.312	0.09	0.02	0.03				0.1683
Na K	1.041	0.64	0.03	0.37				0.7675

Image000

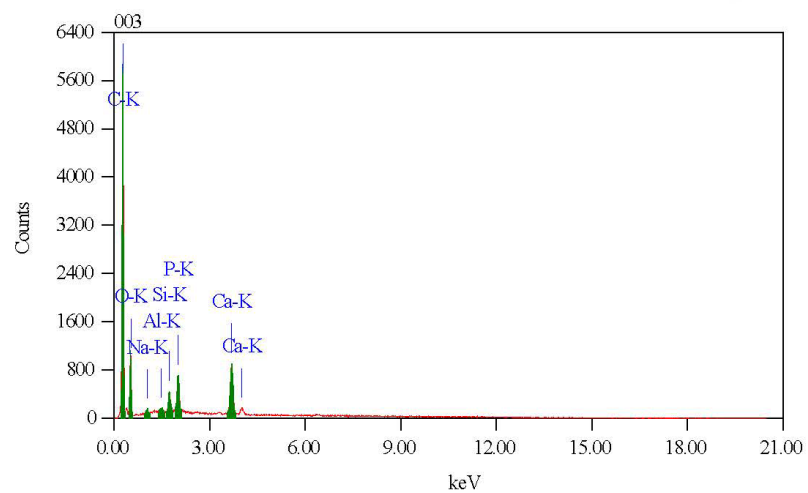
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

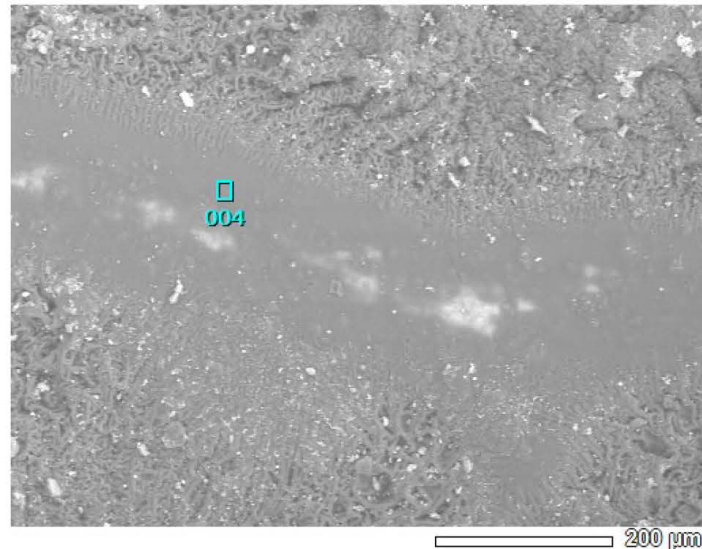
Real Time : 15.00 sec

Live Time : 14.26 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0522

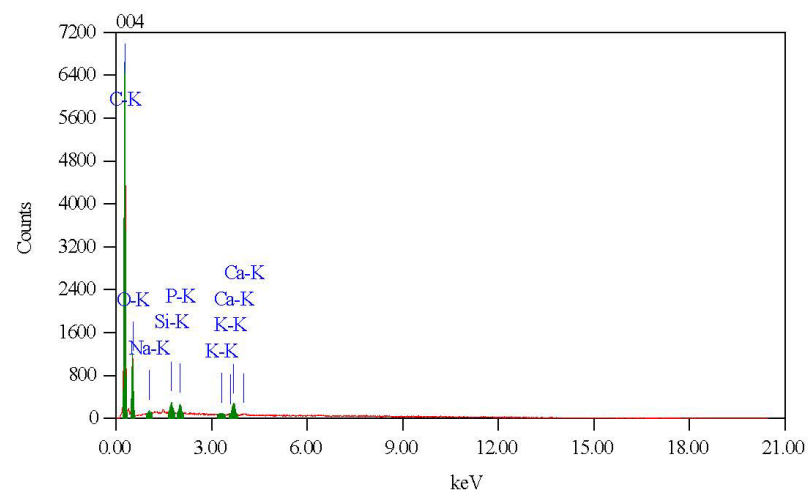
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.11	0.01	0.05				0.1527
C K	0.277	66.94	0.16	75.40				70.6752
Ca K	3.690	3.98	0.05	1.34				8.3364
Na K	1.041	0.28	0.02	0.16				0.3571
O K	0.525	25.62	0.26	21.66				14.4641



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

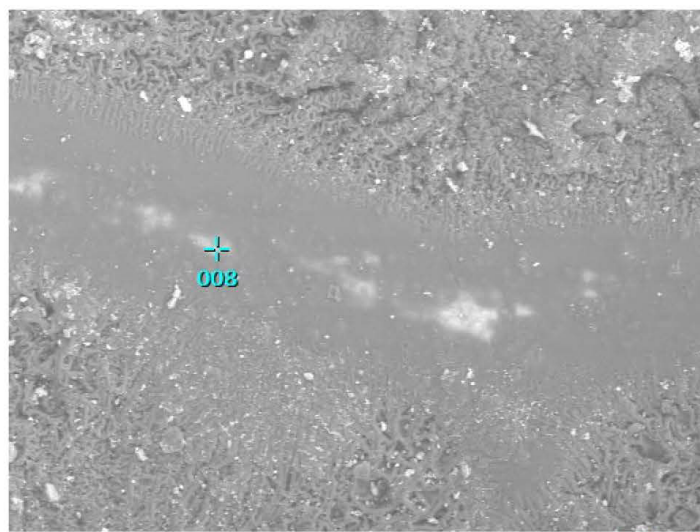
Real Time : 15.00 sec

Live Time : 14.33 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0477

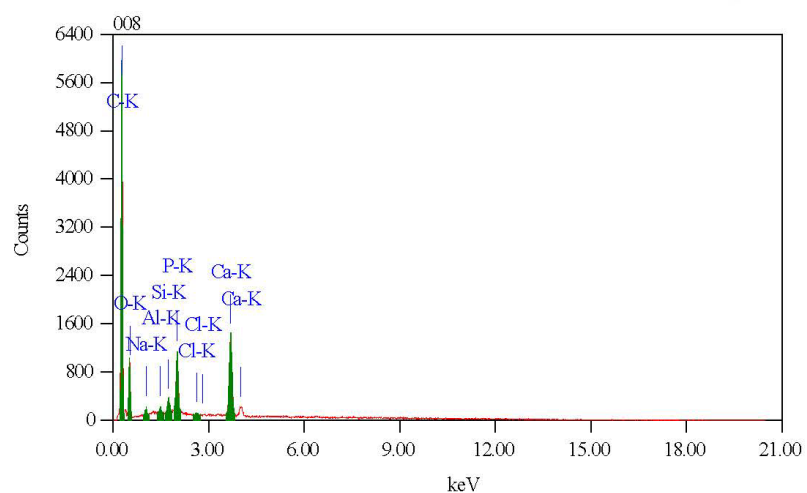
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	69.14	0.15	75.73				80.1334
Ca K	3.690	1.12	0.03	0.37				2.1280
K K	3.312	0.11	0.02	0.04				0.2041
Na K	1.041	0.25	0.02	0.14				0.2917
O K	0.525	28.24	0.28	23.22				15.3038



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 14.15 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0421

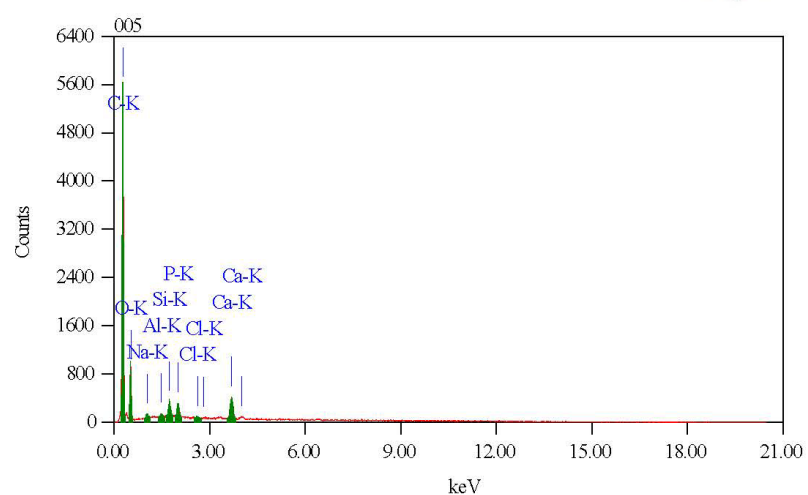
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.18	0.01	0.09				0.2600
C K	0.277	67.13	0.15	76.48				67.1821
Ca K	3.690	5.63	0.05	1.92				11.9643
Cl K	2.621	0.09	0.01	0.03				0.1824
Na K	1.041	0.49	0.02	0.29				0.6547



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 14.37 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0444

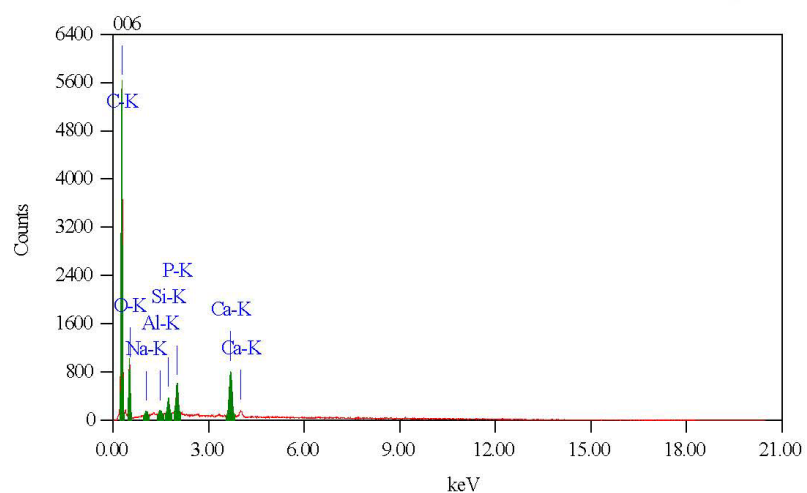
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.15	0.02	0.07				0.2045
C K	0.277	69.07	0.16	76.22				77.3566
Ca K	3.690	1.98	0.04	0.65				3.9384
Cl K	2.621	0.10	0.01	0.04				0.1929
Na K	1.041	0.36	0.03	0.21				0.4478



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

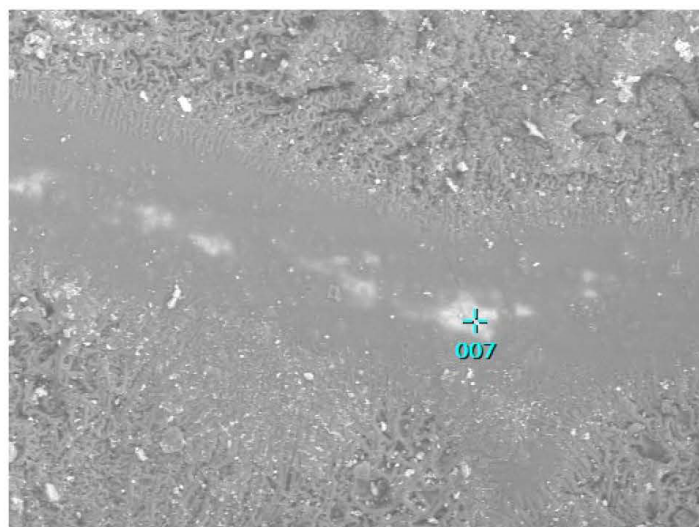
Real Time : 15.00 sec

Live Time : 14.31 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0468

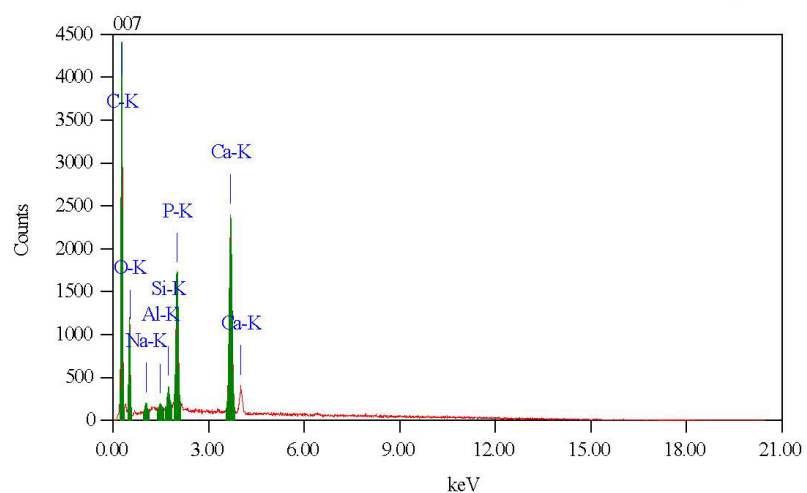
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.17	0.02	0.08				0.2337
C K	0.277	67.63	0.16	75.86				72.3789
Ca K	3.690	3.80	0.05	1.28				7.8152
Na K	1.041	0.33	0.02	0.20				0.4255
O K	0.525	25.42	0.27	21.40				14.0238



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

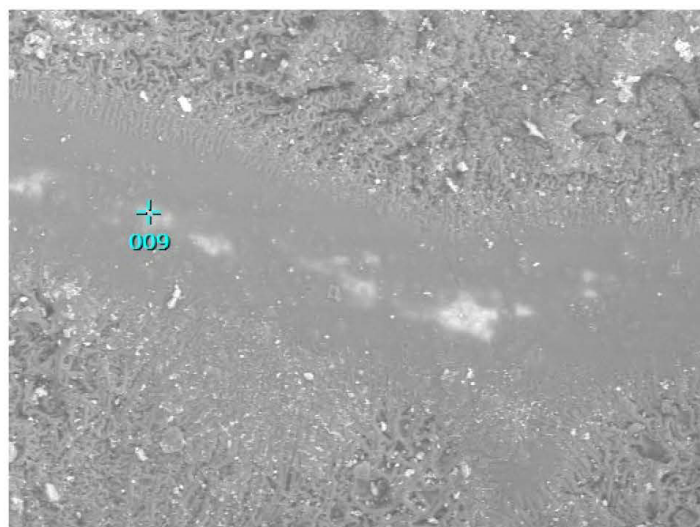
Real Time : 15.00 sec

Live Time : 14.00 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0366

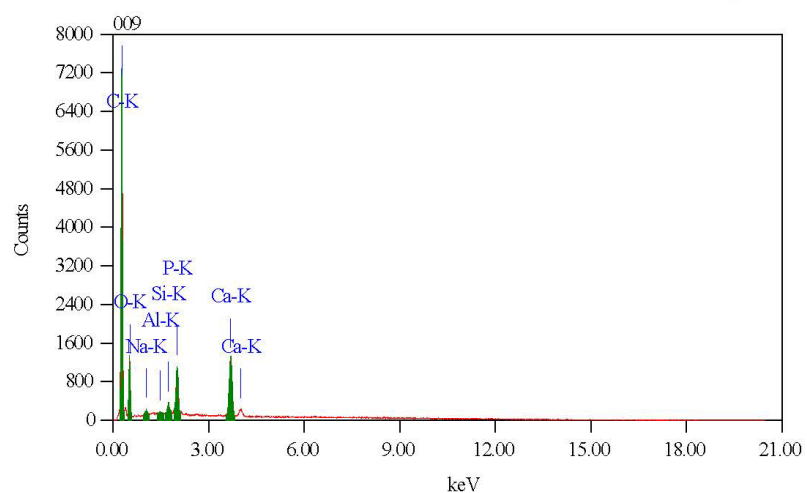
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.11	0.01	0.06				0.1727
C K	0.277	58.66	0.16	70.43				51.0815
Ca K	3.690	9.44	0.07	3.40				21.0056
Na K	1.041	0.42	0.02	0.26				0.5667
O K	0.525	25.74	0.25	23.20				14.9655



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 14.02 sec

ZAF Method Standardless Quantitative Analysis

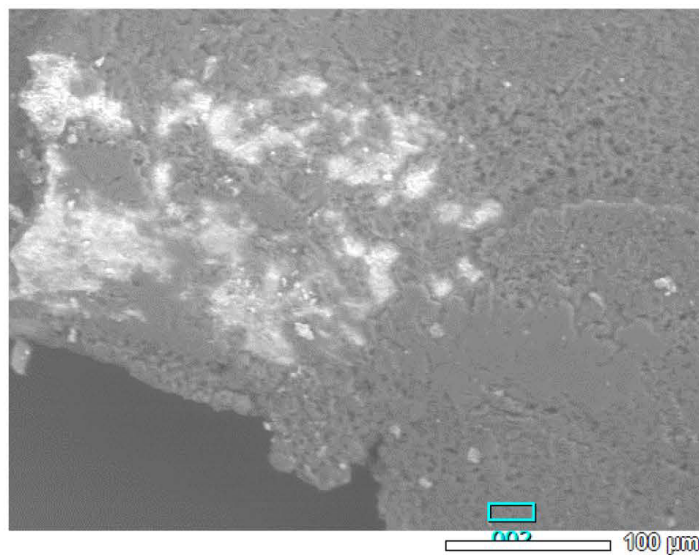
Fitting Coefficient : 0.0432

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.08	0.01	0.04				0.1163
C K	0.277	67.24	0.14	75.94				69.9307
Ca K	3.690	4.56	0.05	1.54				9.5375
Na K	1.041	0.36	0.02	0.21				0.4684
O K	0.525	24.60	0.23	20.86				13.5467

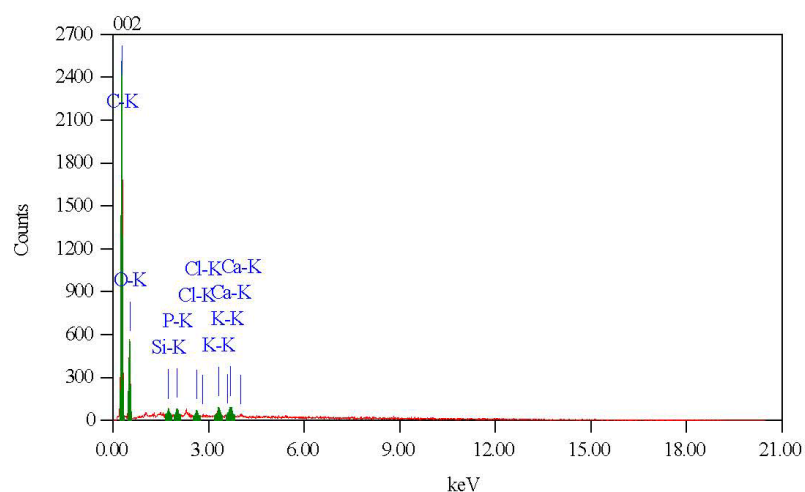
d. Spike Sp2b:

Image000

1/1



Title : IMG1
Instrument : IT300(LA)
Volt : 20.00 kV

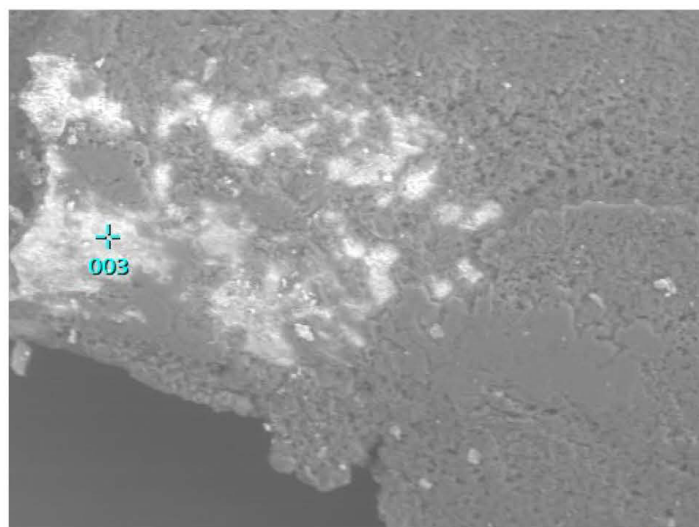


Acquisition Parameter
Instrument : IT300(LA)
Acc. Voltage : 20.0 kV
Probe Current: 7.47500 nA
PHA mode : T3
Real Time : 15.00 sec
Live Time : 14.72 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0607

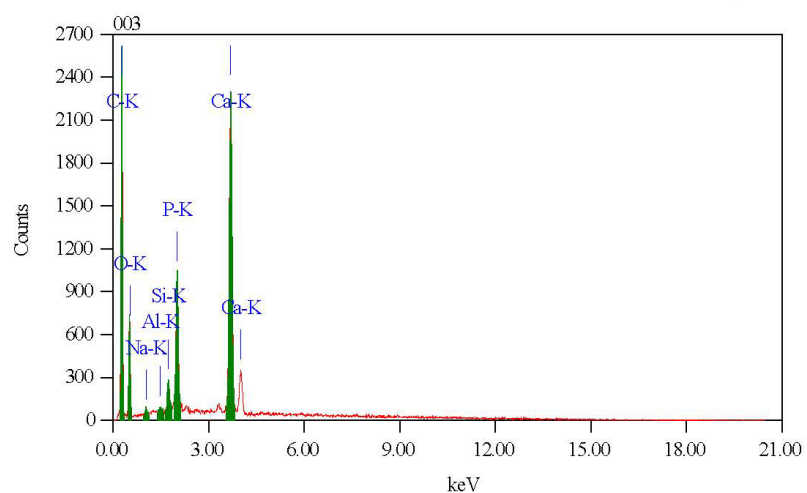
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	65.77	0.23	72.74				76.6107
Ca K	3.690	0.78	0.04	0.26				1.5190
Cl K	2.621	0.34	0.02	0.13				0.6600
K K	3.312	0.71	0.04	0.24				1.3362
O K	0.525	31.69	0.45	26.32				18.6428



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

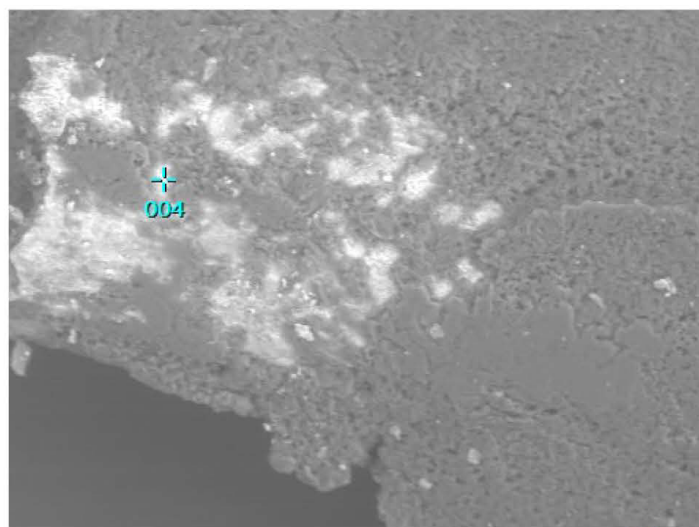
Real Time : 15.00 sec

Live Time : 14.36 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0421

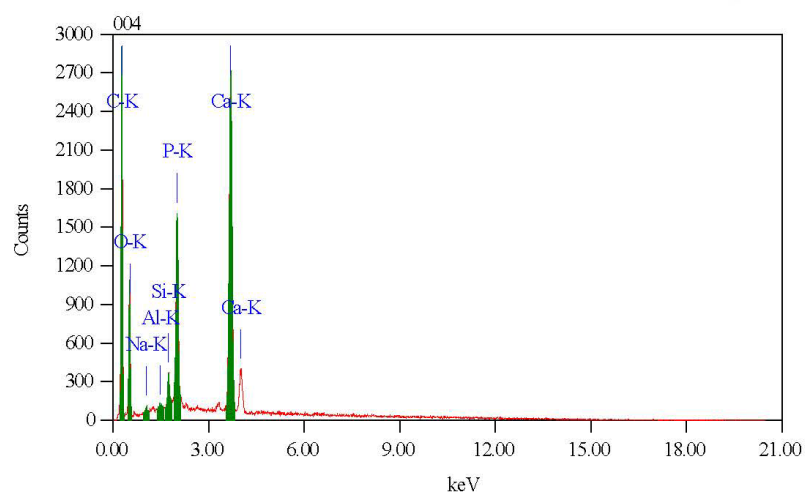
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.08	0.01	0.05				0.1177
C K	0.277	53.48	0.19	67.02				43.8384
Ca K	3.690	14.53	0.10	5.46				30.8323
Na K	1.041	0.27	0.02	0.18				0.3354
O K	0.525	26.15	0.32	24.60				13.7923



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

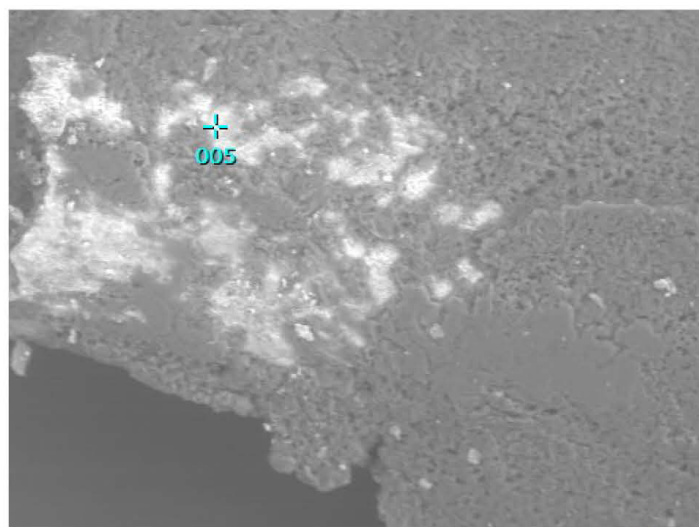
Real Time : 15.00 sec

Live Time : 14.19 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0361

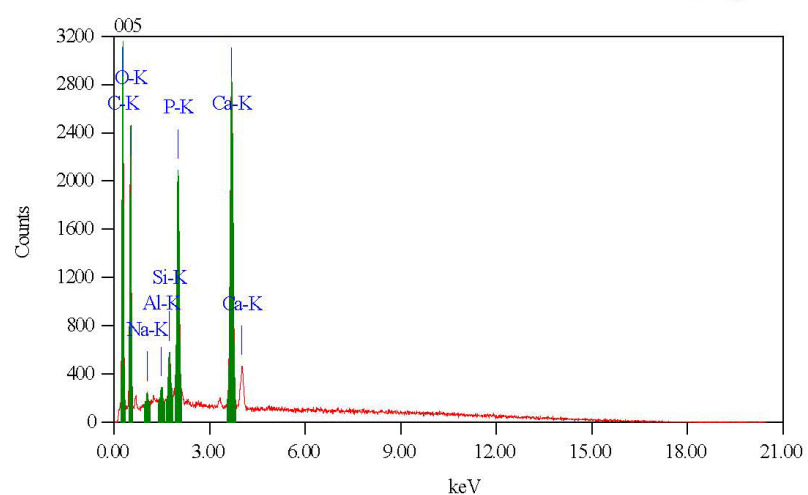
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.09	0.01	0.05				0.1272
C K	0.277	51.10	0.17	64.56				39.7407
Ca K	3.690	13.83	0.09	5.24				30.1004
Na K	1.041	0.25	0.02	0.16				0.3189
O K	0.525	28.23	0.29	26.77				16.0790



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

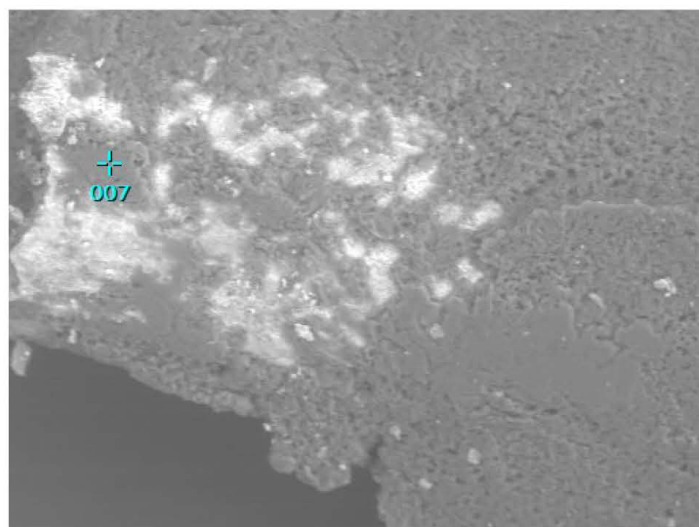
Real Time : 15.00 sec

Live Time : 13.57 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0450

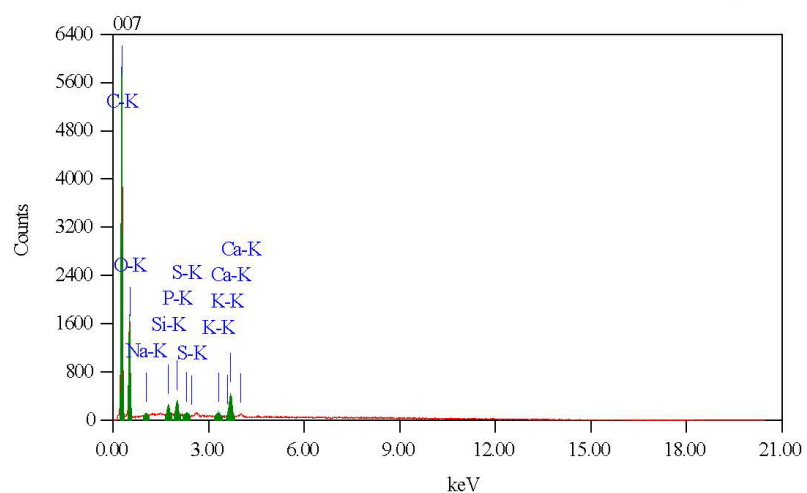
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.23	0.02	0.13				0.3368
C K	0.277	43.40	0.14	55.29				33.0655
Ca K	3.690	10.77	0.07	4.11				24.0499
Na K	1.041	0.41	0.03	0.27				0.5151
O K	0.525	38.55	0.27	36.87				28.0713



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

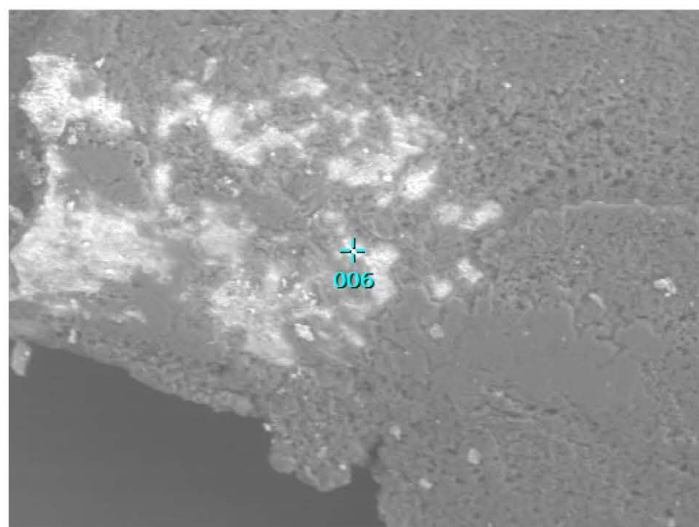
Real Time : 15.00 sec

Live Time : 14.30 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0533

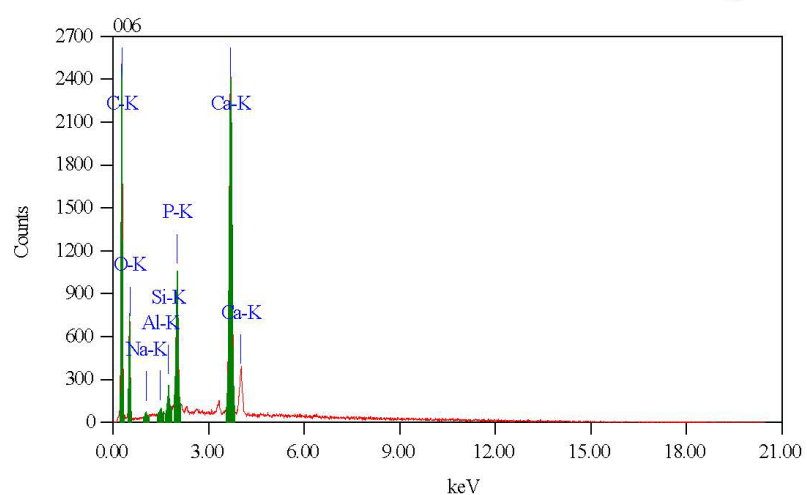
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	61.44	0.14	69.09				70.2349
Ca K	3.690	1.77	0.03	0.60				3.5924
K K	3.312	0.27	0.02	0.09				0.5256
Na K	1.041	0.20	0.02	0.12				0.2343
O K	0.525	34.91	0.28	29.47				22.7561



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

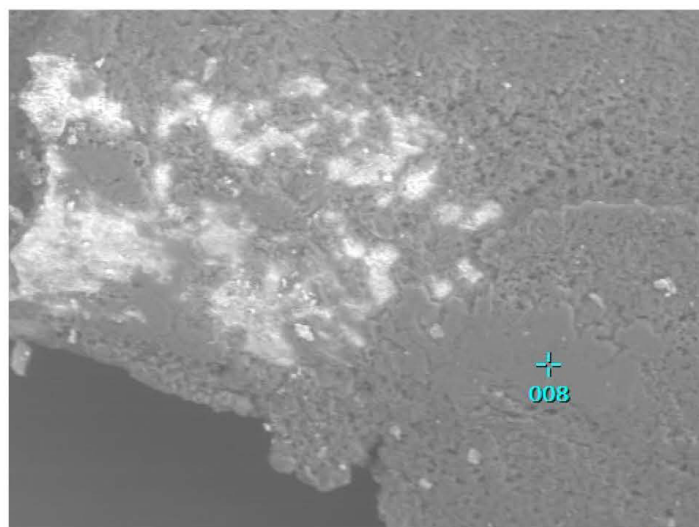
Real Time : 15.00 sec

Live Time : 14.35 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0434

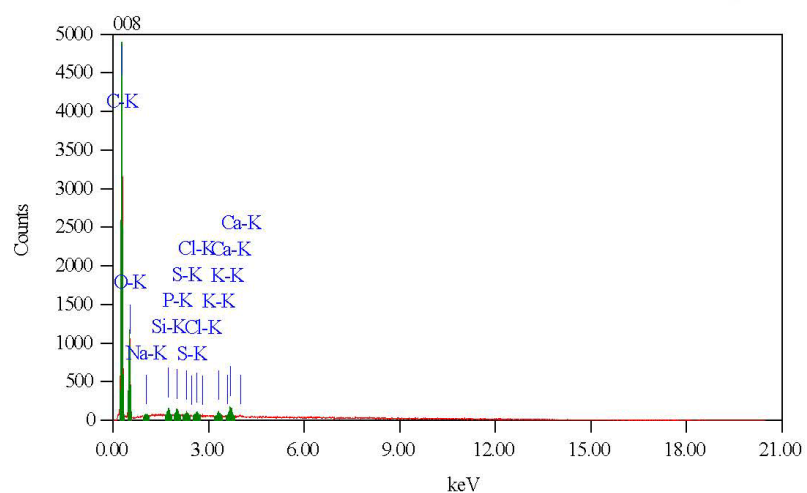
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.13	0.01	0.08				0.1844
C K	0.277	52.14	0.18	65.96				42.6942
Ca K	3.690	15.72	0.11	5.96				32.8628
Na K	1.041	0.22	0.02	0.15				0.2734
O K	0.525	26.66	0.33	25.31				13.7488



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 14.51 sec

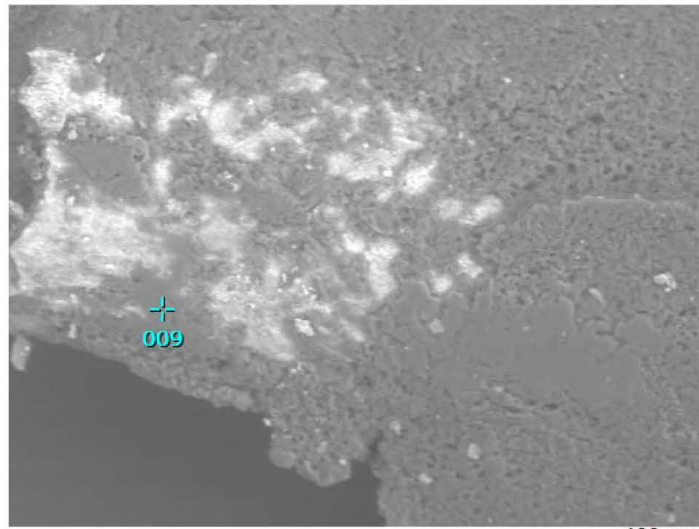
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0532

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	65.85	0.17	72.71				76.8939
Ca K	3.690	0.79	0.03	0.26				1.5457
Cl K	2.621	0.14	0.01	0.05				0.2788
K K	3.312	0.37	0.02	0.13				0.7038
Na K	1.041	0.16	0.02	0.09				0.1861
O K	0.525	31.82	0.33	26.38				18.8588

Image000

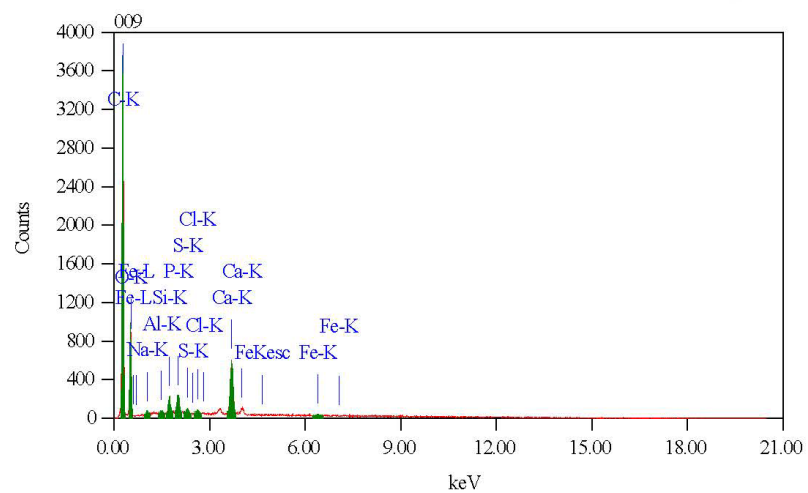
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 14.56 sec

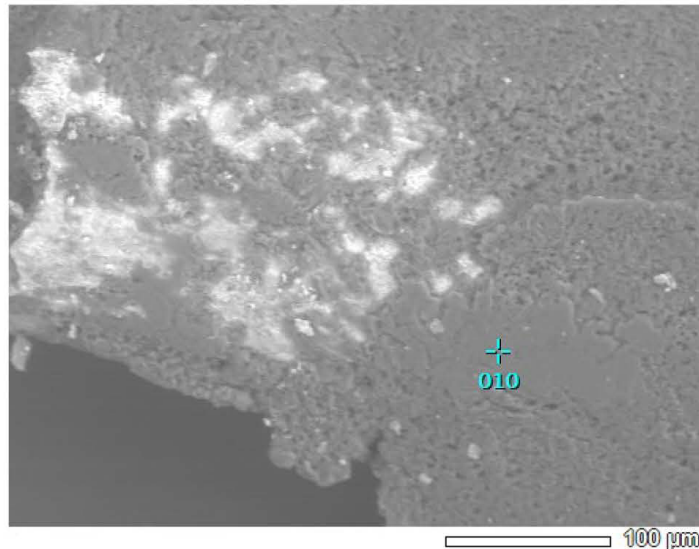
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0489

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.08	0.01	0.04				0.1133
C K	0.277	63.11	0.18	71.60				69.1242
Ca K	3.690	3.85	0.06	1.31				7.9373
Cl K	2.621	0.16	0.02	0.06				0.3195
Fe K	6.398	0.24	0.03	0.06				0.3905
Na K	1.041	0.21	0.02	0.12				0.2586

JED-2300 AnalysisStation

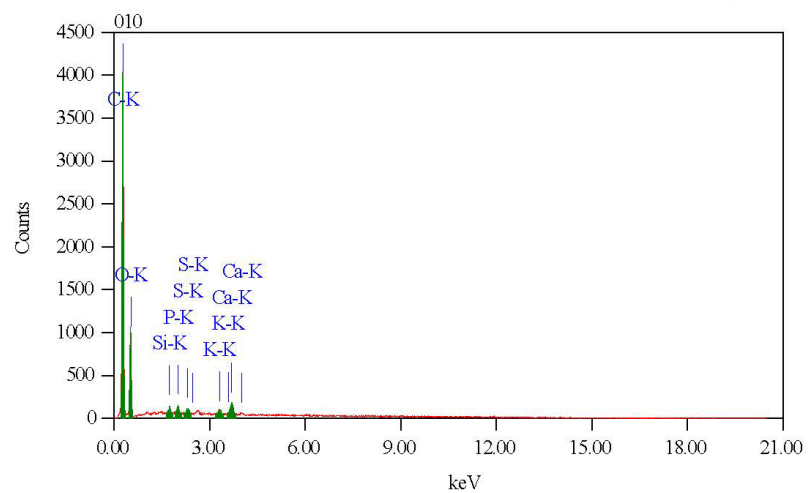
JEOL



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

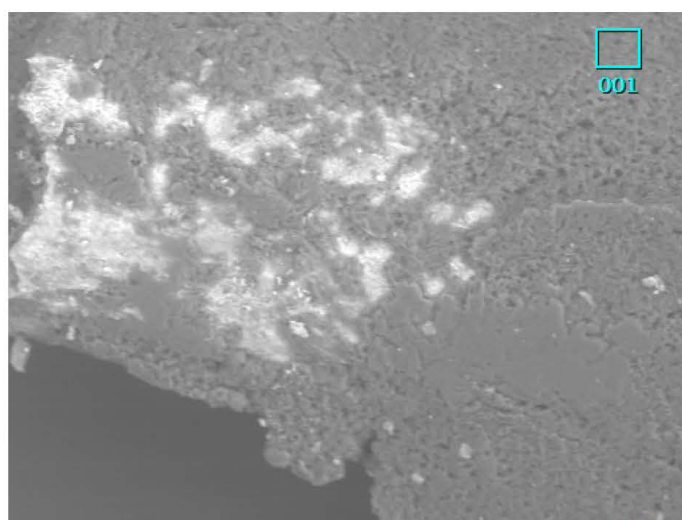
Real Time : 15.00 sec

Live Time : 14.56 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0493

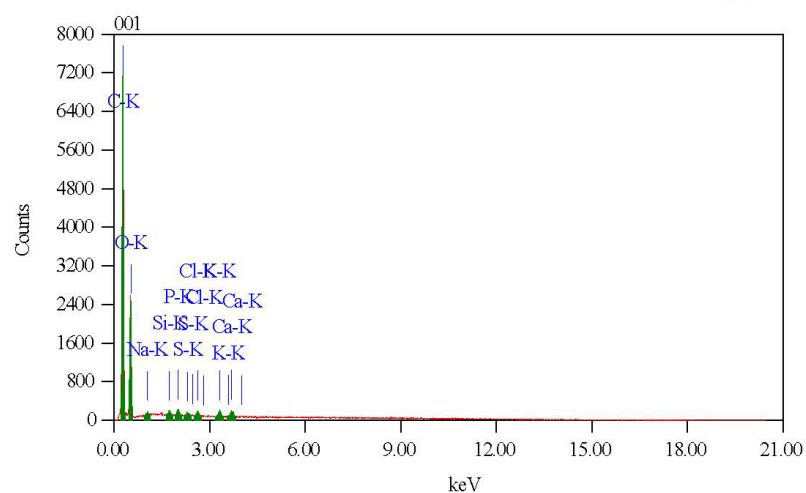
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	64.21	0.18	71.26				74.9974
Ca K	3.690	1.03	0.03	0.34				2.0243
K K	3.312	0.31	0.02	0.11				0.5940
O K	0.525	33.40	0.35	27.83				20.4709
P K	2.013	0.50	0.02	0.21				0.9639



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 14.15 sec

ZAF Method Standardless Quantitative Analysis

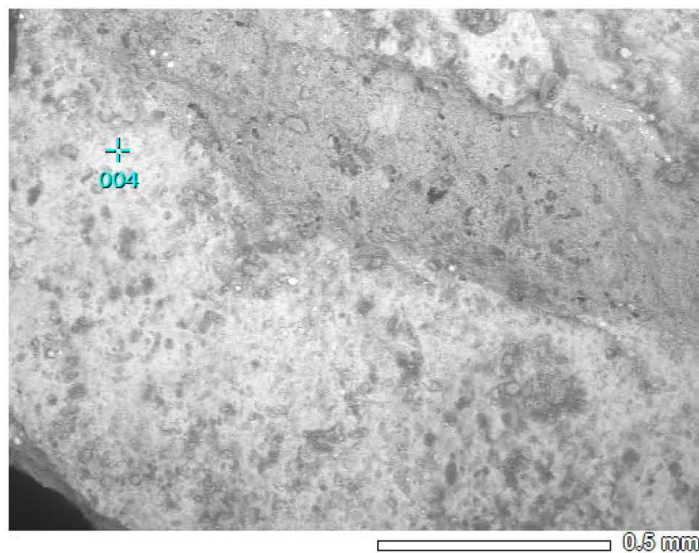
Fitting Coefficient : 0.0472

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
C K	0.277	59.55	0.12	66.83				69.1841
Ca K	3.690	0.42	0.02	0.14				0.8509
Cl K	2.621	0.26	0.01	0.10				0.5123
K K	3.312	0.47	0.02	0.16				0.9229
Na K	1.041	0.25	0.02	0.15				0.2971
O K	0.525	38.34	0.25	32.30				26.9032

e. Scutate scale Sp3a:

Image000

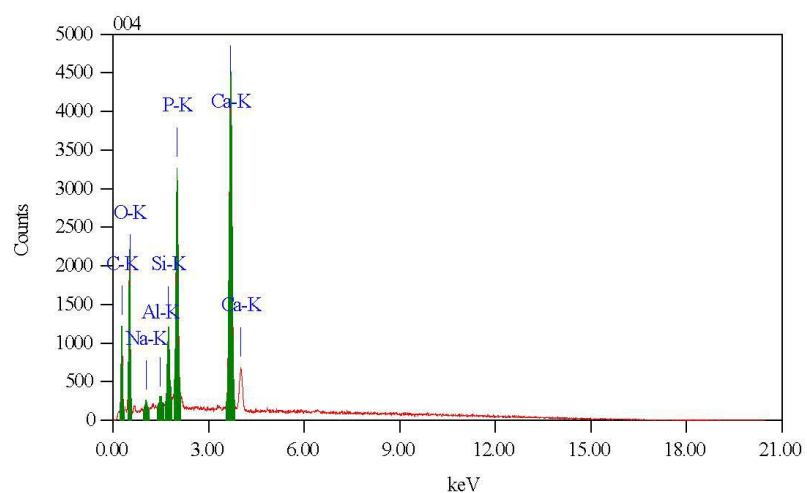
1/1



Title : IMG1

Instrument : IT300 (LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300 (LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

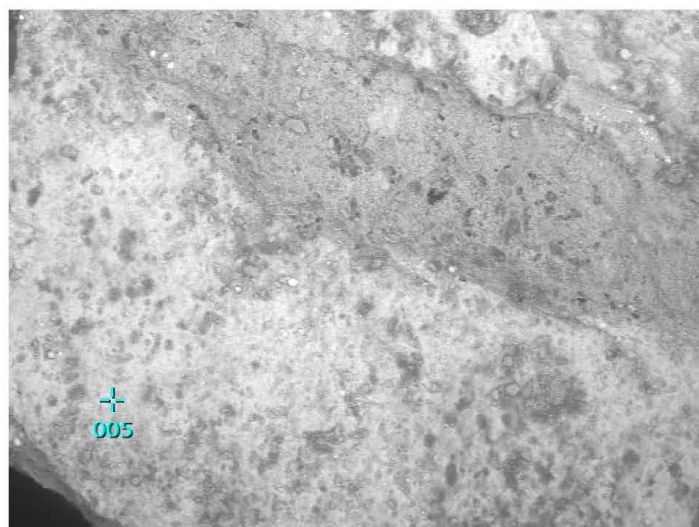
Real Time : 15.00 sec

Live Time : 13.37 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0394

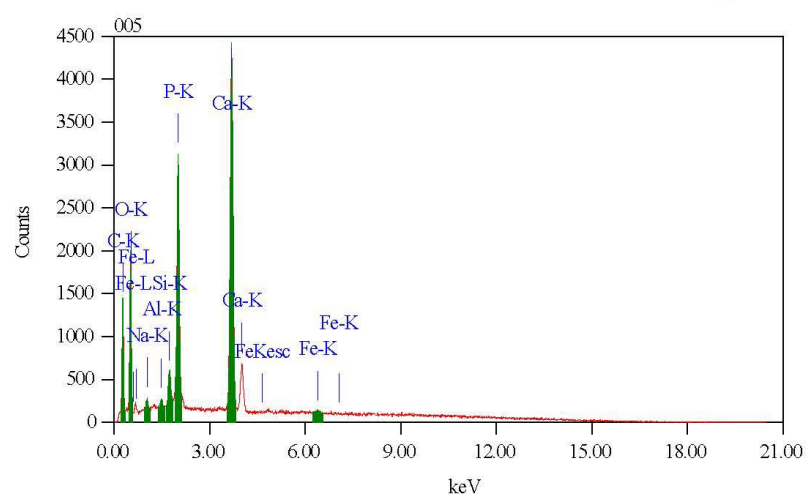
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.28	0.02	0.19				0.3552
C K	0.277	26.11	0.14	38.51				11.9177
Ca K	3.690	19.99	0.10	8.83				38.8738
Na K	1.041	0.54	0.03	0.41				0.5826
O K	0.525	40.28	0.30	44.60				25.4439



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

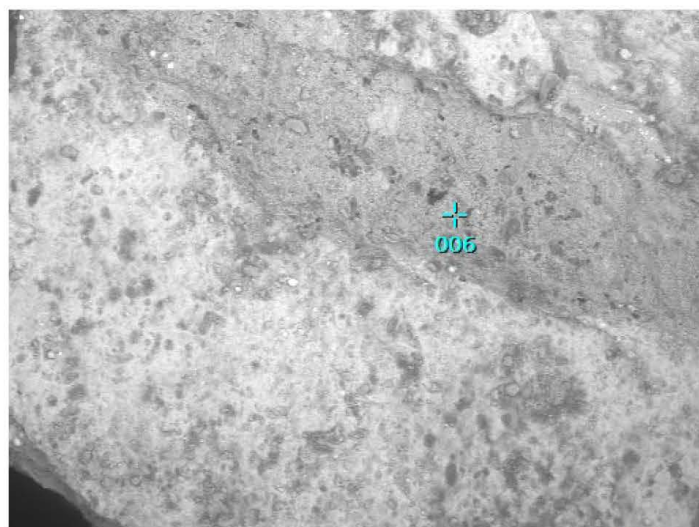
Real Time : 15.00 sec

Live Time : 13.40 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0366

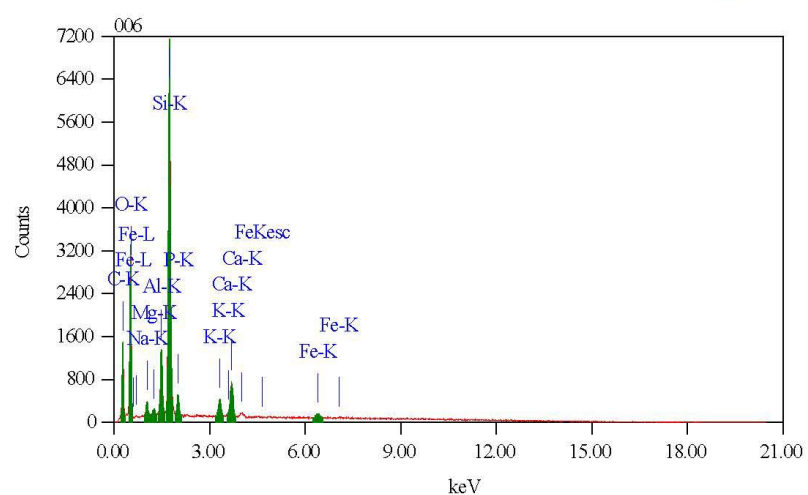
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.25	0.02	0.16				0.3166
C K	0.277	29.37	0.15	42.44				14.7485
Ca K	3.690	19.37	0.10	8.39				38.4335
Fe K	6.398	0.50	0.04	0.15				0.7941
Na K	1.041	0.63	0.03	0.48				0.6935



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

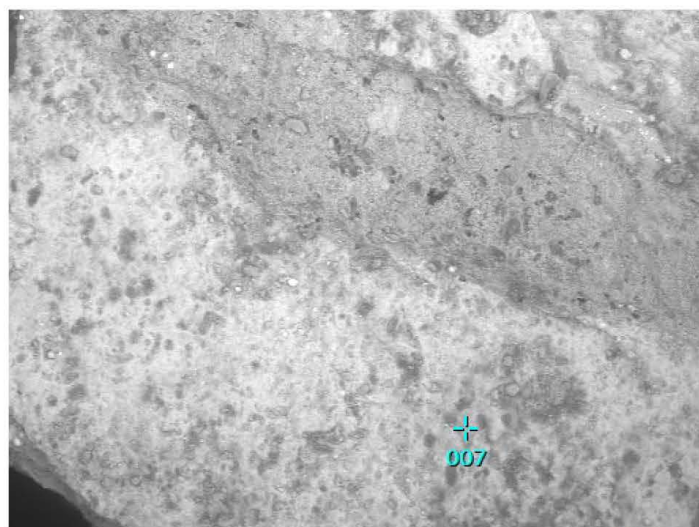
Real Time : 15.00 sec

Live Time : 13.62 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0537

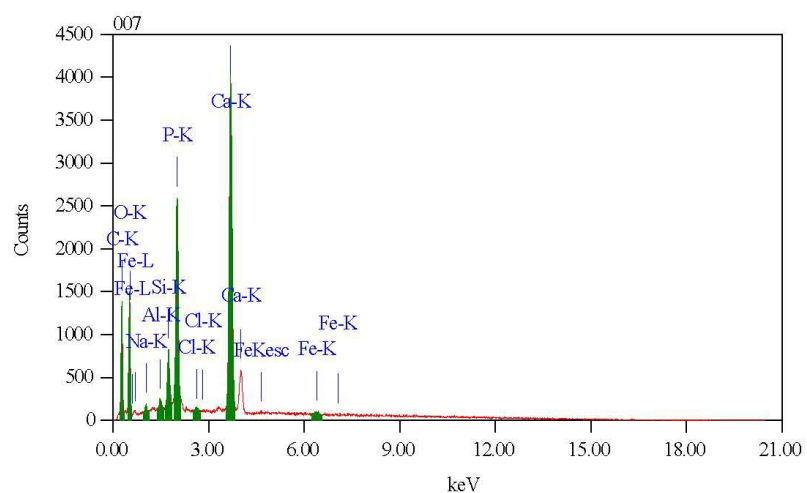
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	2.45	0.03	1.46				3.7676
C K	0.277	35.42	0.17	47.26				15.7303
Ca K	3.690	2.58	0.04	1.03				5.6720
Fe K	6.398	1.00	0.04	0.29				1.8401
K K	3.312	1.24	0.03	0.51				2.6026
Mg K	1.253	0.25	0.02	0.16				0.3120



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

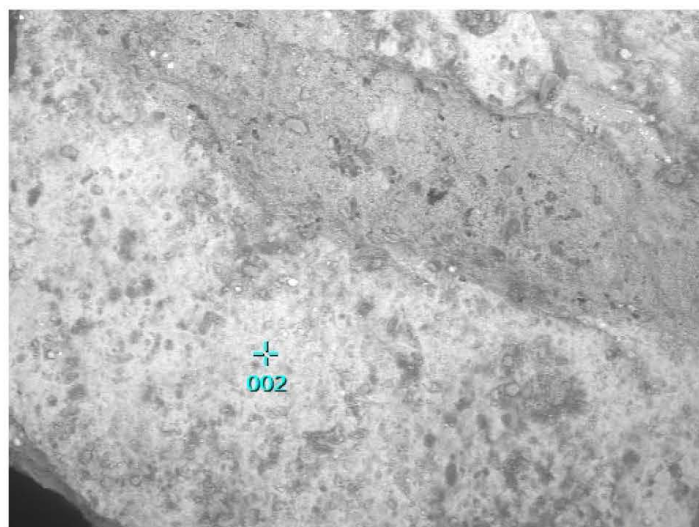
Real Time : 15.00 sec

Live Time : 13.81 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0372

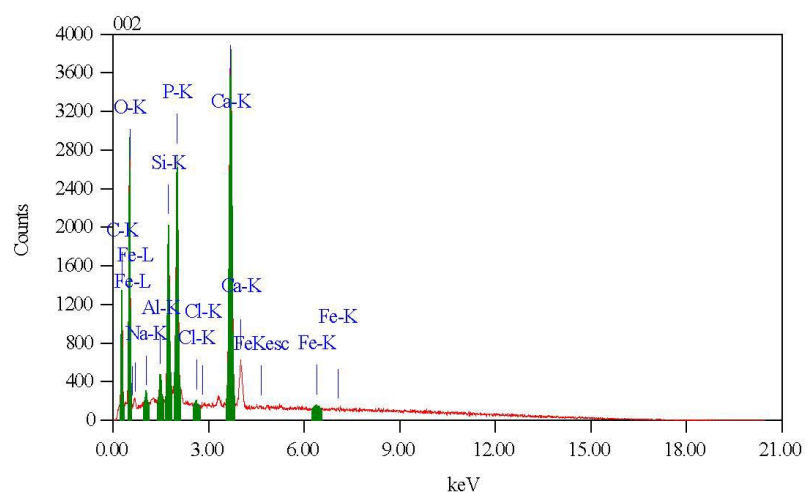
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.30	0.02	0.19				0.3877
C K	0.277	32.29	0.16	46.56				16.1015
Ca K	3.690	20.20	0.11	8.73				40.3020
Cl K	2.621	0.12	0.02	0.06				0.2178
Fe K	6.398	0.61	0.04	0.19				0.9803
Na K	1.041	0.52	0.03	0.39				0.5871



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

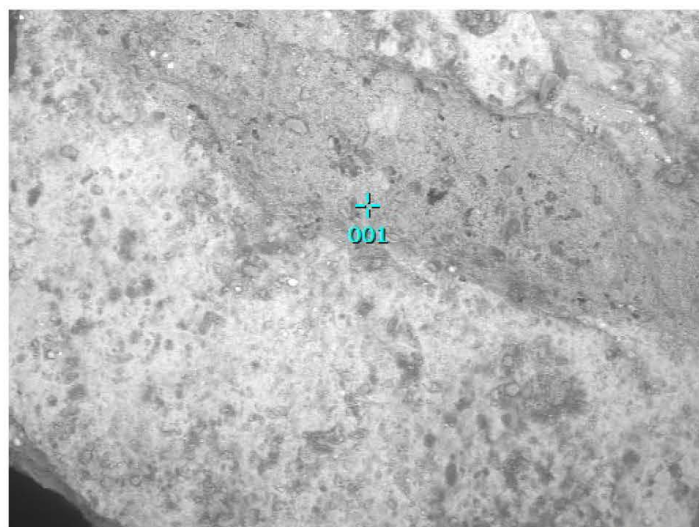
Real Time : 15.00 sec

Live Time : 13.25 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0439

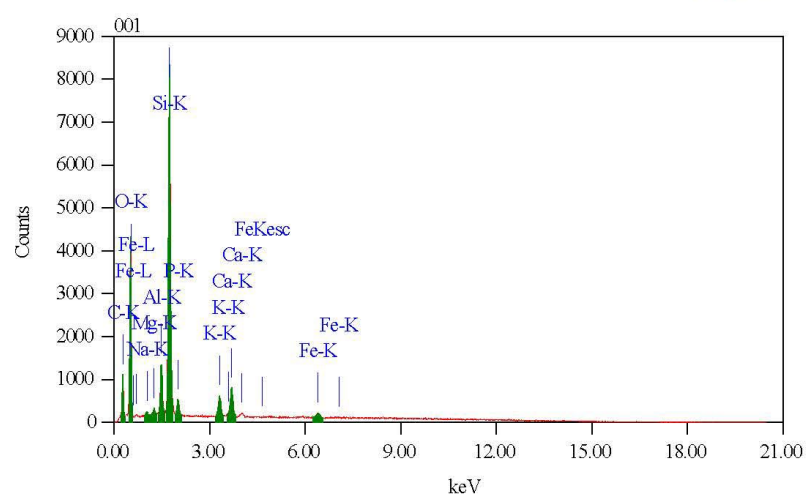
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.65	0.02	0.41				0.8416
C K	0.277	26.67	0.14	38.21				12.6442
Ca K	3.690	15.47	0.09	6.64				31.0103
Cl K	2.621	0.09	0.01	0.04				0.1596
Fe K	6.398	0.40	0.04	0.12				0.6442
Na K	1.041	0.50	0.03	0.38				0.5631



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

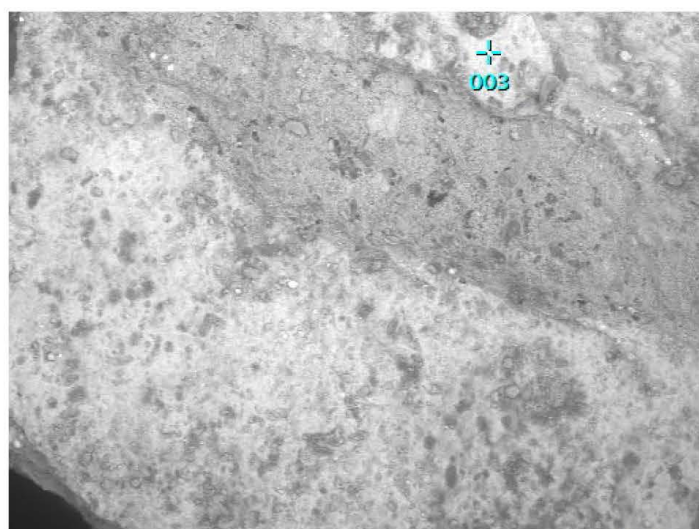
Real Time : 15.00 sec

Live Time : 13.26 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0571

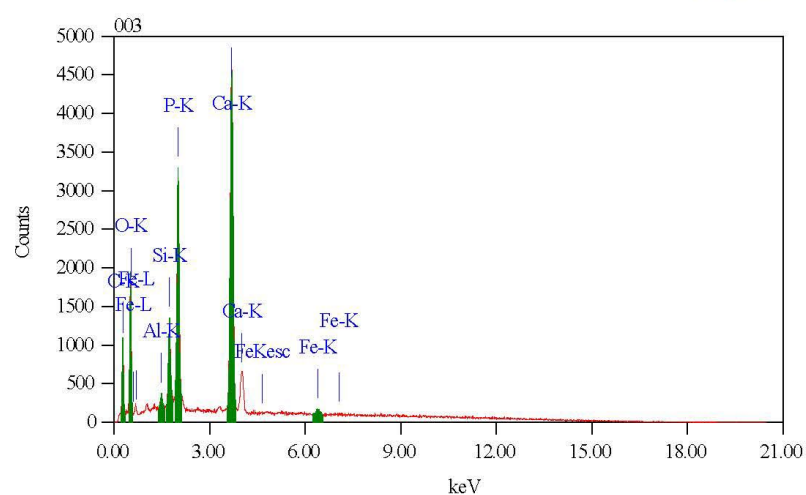
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	2.48	0.03	1.53				3.3946
C K	0.277	27.40	0.15	38.12				9.9301
Ca K	3.690	2.66	0.04	1.11				5.2333
Fe K	6.398	1.19	0.05	0.36				1.9727
K K	3.312	1.88	0.03	0.80				3.5342
Mg K	1.253	0.35	0.02	0.24				0.4014



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

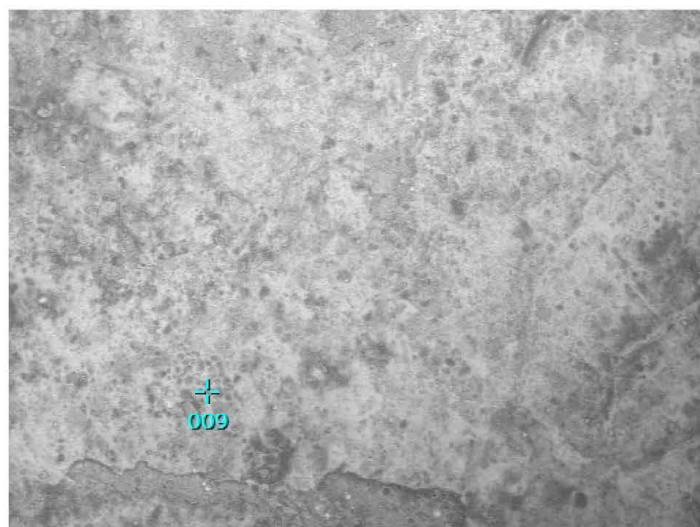
Real Time : 15.00 sec

Live Time : 13.34 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0348

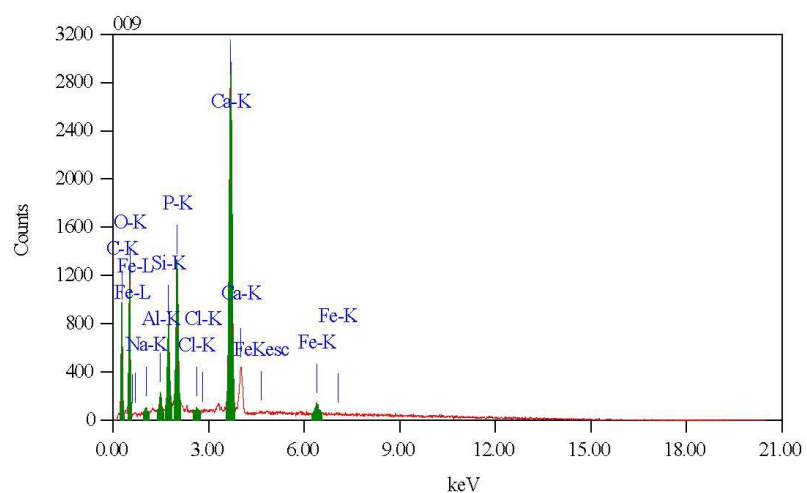
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.43	0.02	0.29				0.5276
C K	0.277	24.43	0.14	37.05				10.2118
Ca K	3.690	21.16	0.11	9.61				39.9487
Fe K	6.398	1.06	0.05	0.34				1.6163
O K	0.525	38.90	0.30	44.28				23.5874



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

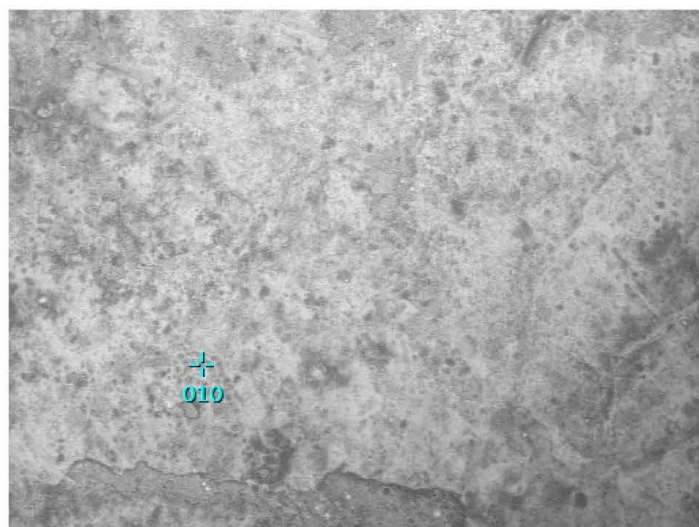
Real Time : 15.00 sec

Live Time : 14.13 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0438

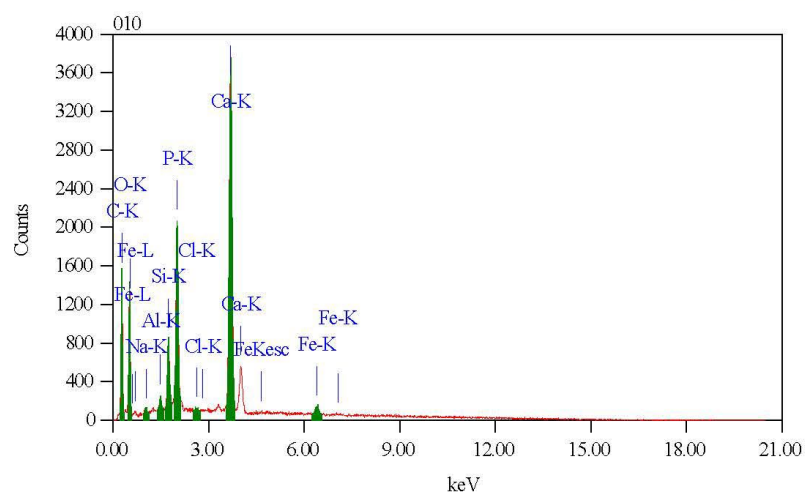
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.58	0.03	0.38				0.7198
C K	0.277	29.40	0.17	42.99				15.6684
Ca K	3.690	20.68	0.13	9.06				40.7595
Cl K	2.621	0.11	0.02	0.06				0.2106
Fe K	6.398	1.90	0.07	0.60				2.9961
Na K	1.041	0.37	0.03	0.28				0.3937



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.94 sec

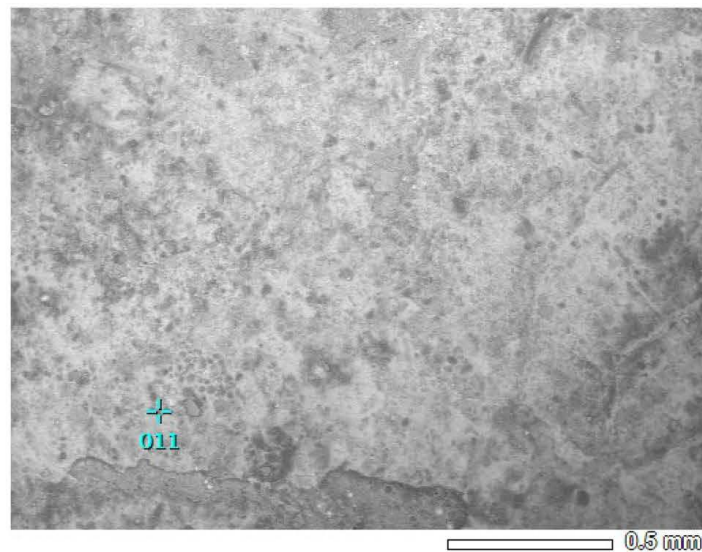
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0380

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.37	0.02	0.23				0.4857
C K	0.277	35.15	0.16	49.69				19.4371
Ca K	3.690	19.03	0.10	8.06				38.7743
Cl K	2.621	0.09	0.01	0.05				0.1806
Fe K	6.398	1.42	0.05	0.43				2.3209
Na K	1.041	0.30	0.03	0.22				0.3402

Image001

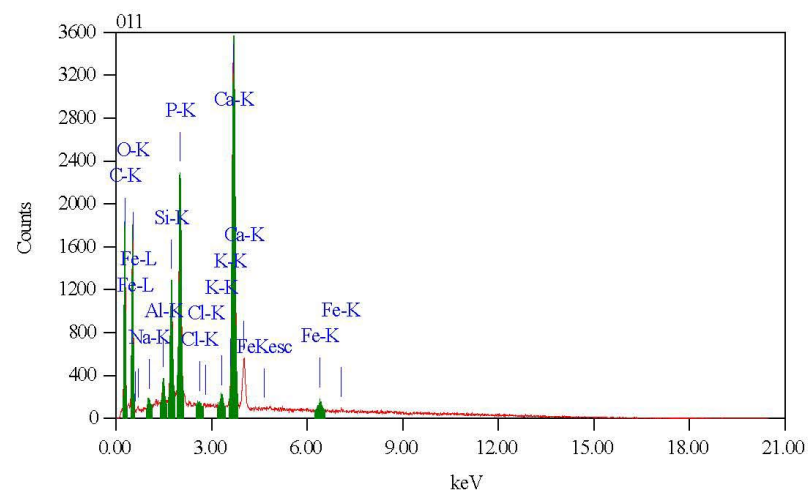
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

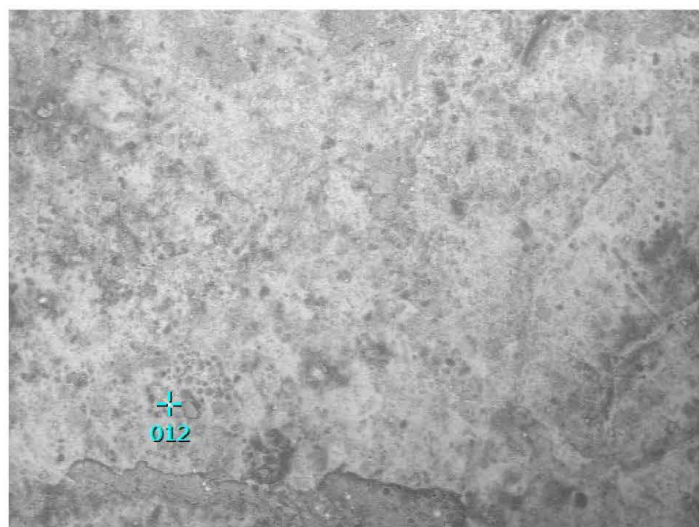
Real Time : 15.00 sec

Live Time : 13.79 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0356

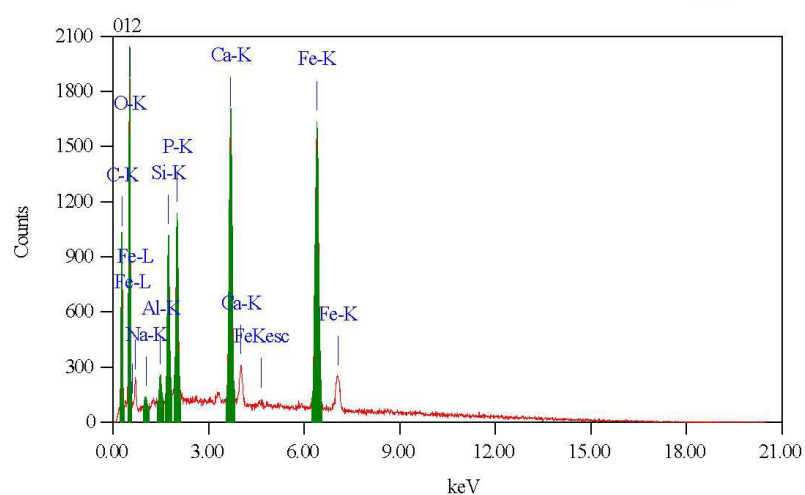
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.57	0.02	0.35				0.7771
C K	0.277	36.59	0.16	50.68				20.4064
Ca K	3.690	15.82	0.09	6.57				33.1818
Cl K	2.621	0.13	0.01	0.06				0.2482
Fe K	6.398	1.19	0.05	0.36				2.0216
K K	3.312	0.49	0.02	0.21				1.0104



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

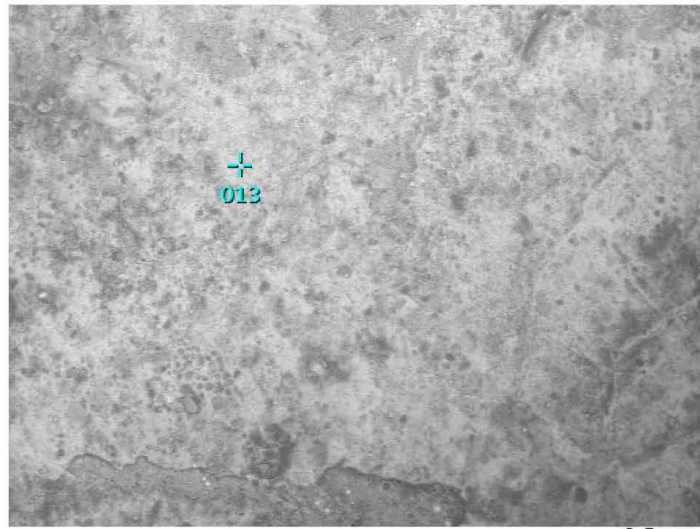
Real Time : 15.00 sec

Live Time : 13.88 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0343

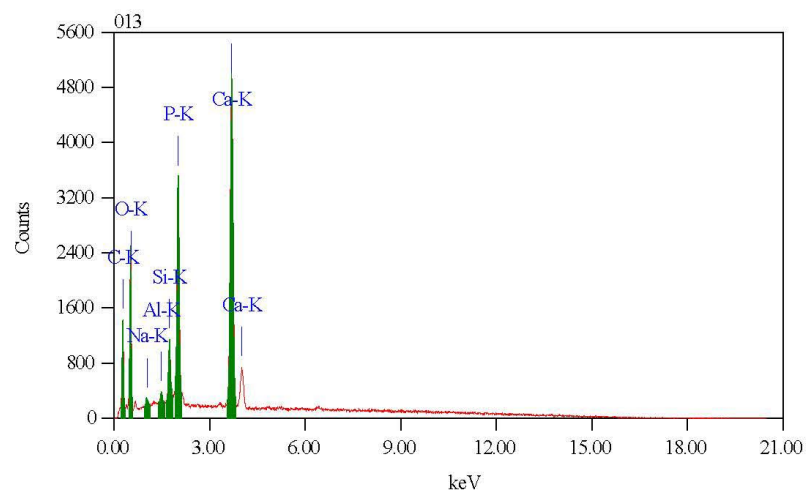
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.51	0.02	0.37				0.4746
C K	0.277	26.30	0.15	43.35				11.4198
Ca K	3.690	8.47	0.07	4.18				14.7383
Fe K	6.398	26.52	0.19	9.40				37.8664
Na K	1.041	0.34	0.03	0.29				0.2499



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.08 sec

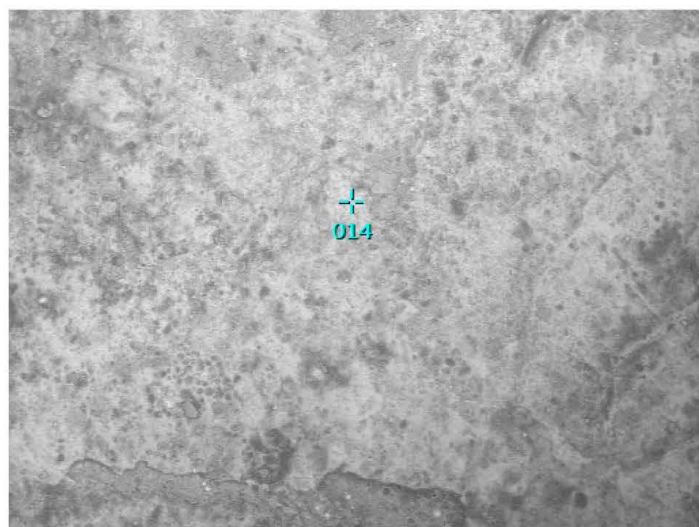
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0389

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.38	0.02	0.25				0.4811
C K	0.277	26.78	0.14	39.16				12.5790
Ca K	3.690	19.43	0.10	8.51				38.1003
Na K	1.041	0.42	0.03	0.32				0.4587
O K	0.525	40.71	0.28	44.69				26.0901

Image001

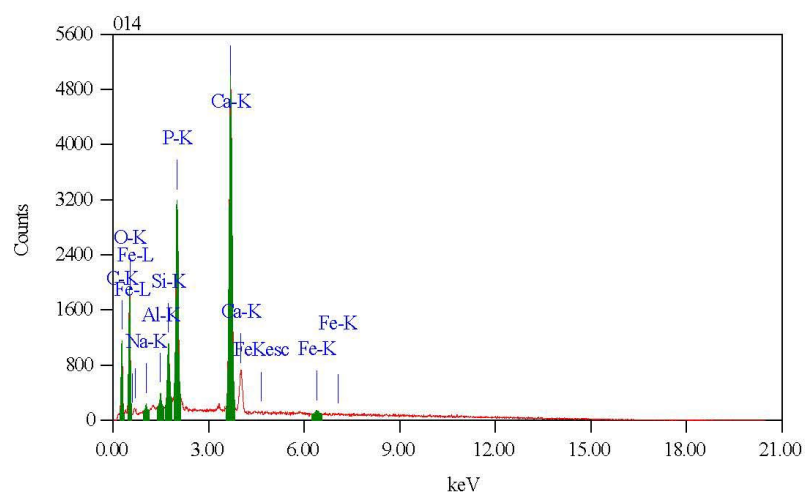
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.45 sec

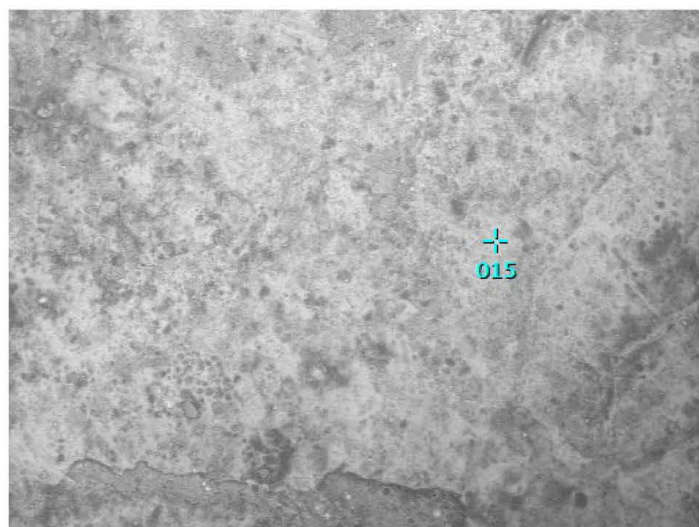
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0322

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.37	0.02	0.25				0.4453
C K	0.277	25.16	0.14	38.00				11.0106
Ca K	3.690	21.95	0.11	9.93				41.6060
Fe K	6.398	0.74	0.04	0.24				1.1360
Na K	1.041	0.48	0.03	0.38				0.5007

Image001

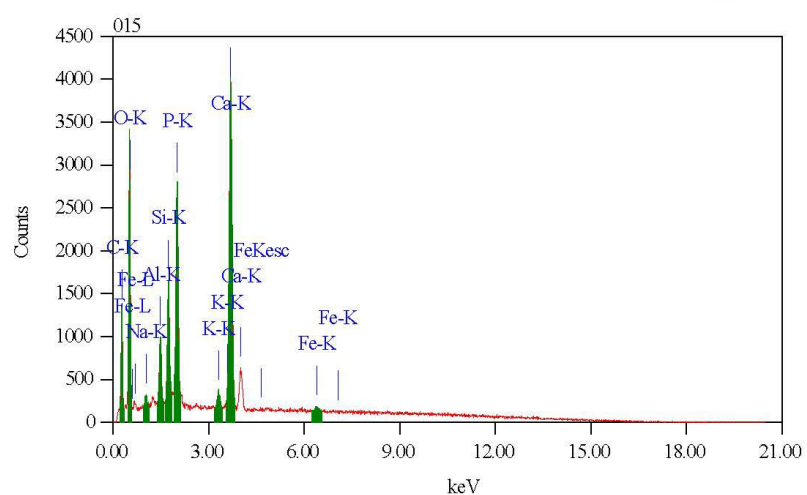
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

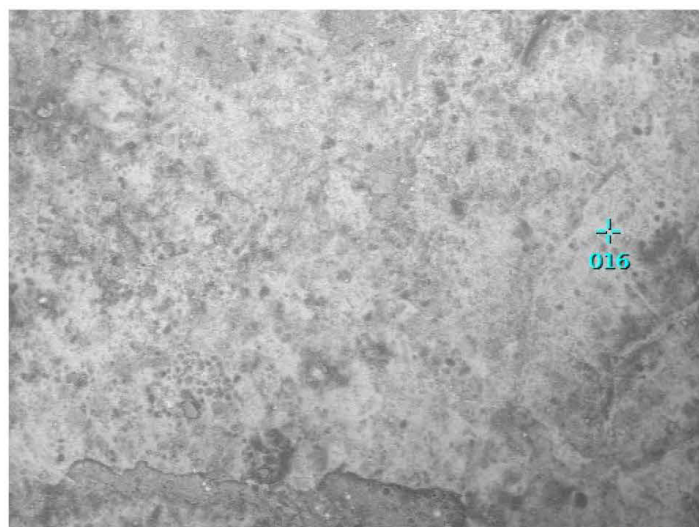
Real Time : 15.00 sec

Live Time : 13.07 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0439

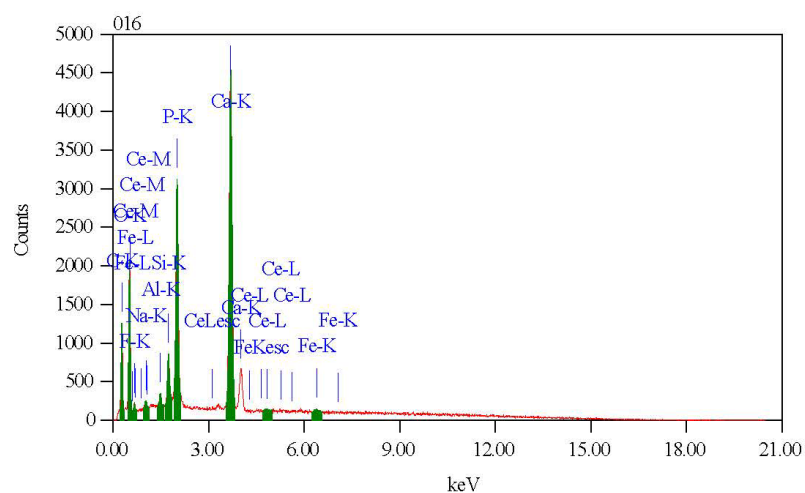
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	1.80	0.03	1.16				2.2632
C K	0.277	24.50	0.13	35.51				11.6124
Ca K	3.690	15.26	0.08	6.63				29.8993
Fe K	6.398	0.60	0.04	0.19				0.9620
K K	3.312	0.77	0.02	0.34				1.4823
Na K	1.041	0.55	0.03	0.42				0.6004



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.34 sec

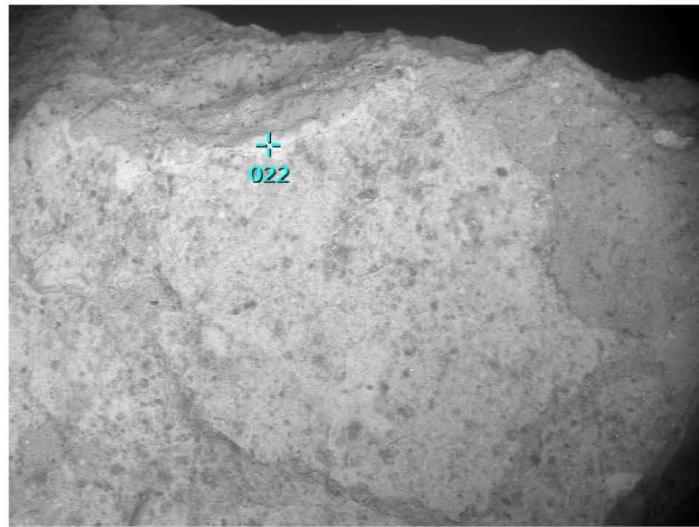
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0372

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.40	0.02	0.26				0.4873
C K	0.277	26.35	0.14	39.12				12.2989
Ca K	3.690	20.05	0.10	8.92				38.6126
Ce L	4.837	0.57	0.07	0.07				0.8162
F K	0.677	1.25	0.12	1.18				1.3452
Fe K	6.398	0.49	0.04	0.16				0.7652

Image002

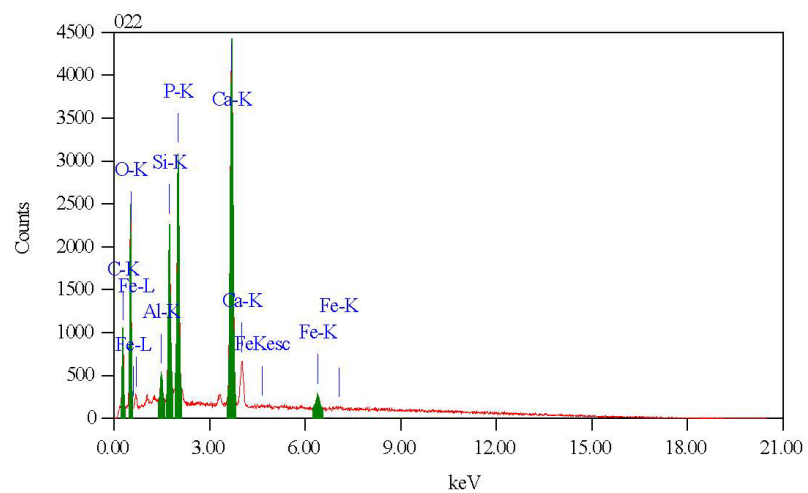
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.16 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0402

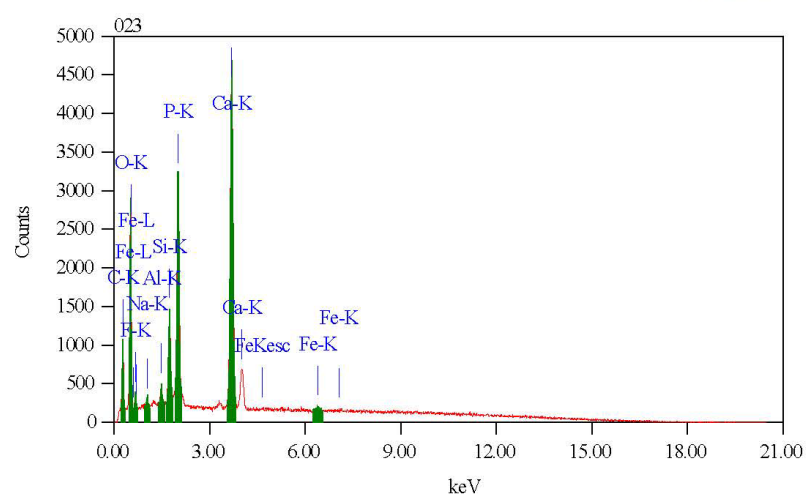
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.78	0.02	0.53				0.9439
C K	0.277	22.64	0.14	34.41				9.0561
Ca K	3.690	18.50	0.10	8.43				34.8559
Fe K	6.398	2.17	0.06	0.71				3.3259
O K	0.525	41.08	0.28	46.87				27.5518



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 12.81 sec

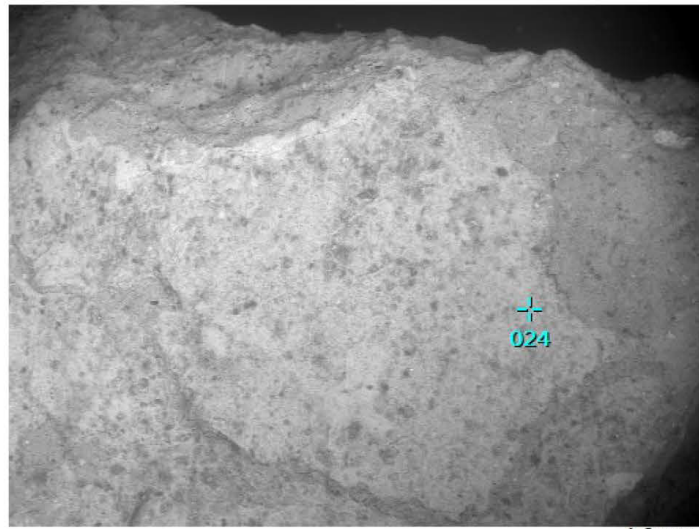
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0391

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.57	0.02	0.38				0.6652
C K	0.277	20.37	0.13	30.84				8.4425
Ca K	3.690	18.53	0.10	8.41				34.3186
F K	0.677	3.54	0.12	3.38				3.6953
Fe K	6.398	0.71	0.05	0.23				1.0716
Na K	1.041	0.57	0.03	0.45				0.5678

Image002

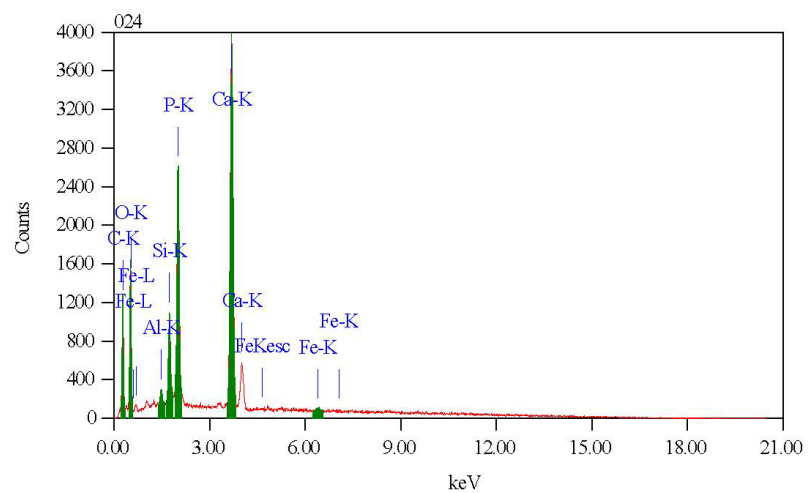
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

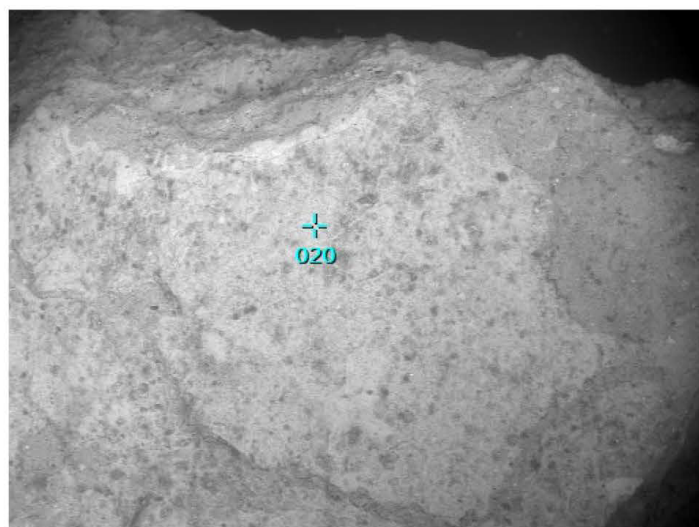
Real Time : 15.00 sec

Live Time : 13.71 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0379

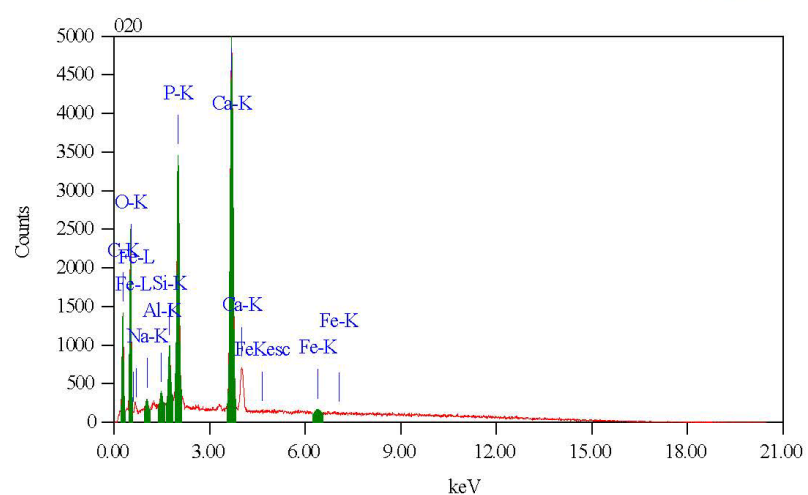
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.41	0.02	0.27				0.5380
C K	0.277	30.11	0.16	43.68				14.4503
Ca K	3.690	19.63	0.11	8.53				39.0469
Fe K	6.398	0.44	0.04	0.14				0.7080
O K	0.525	36.94	0.31	40.22				22.5468



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.12 sec

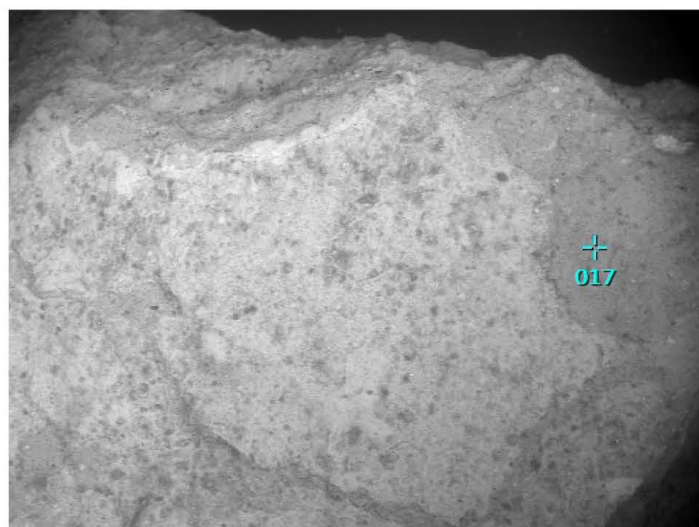
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0372

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.41	0.02	0.27				0.5075
C K	0.277	26.71	0.13	39.19				12.7289
Ca K	3.690	19.57	0.10	8.61				38.2088
Fe K	6.398	0.59	0.04	0.19				0.9329
Na K	1.041	0.64	0.03	0.49				0.6858

Image002

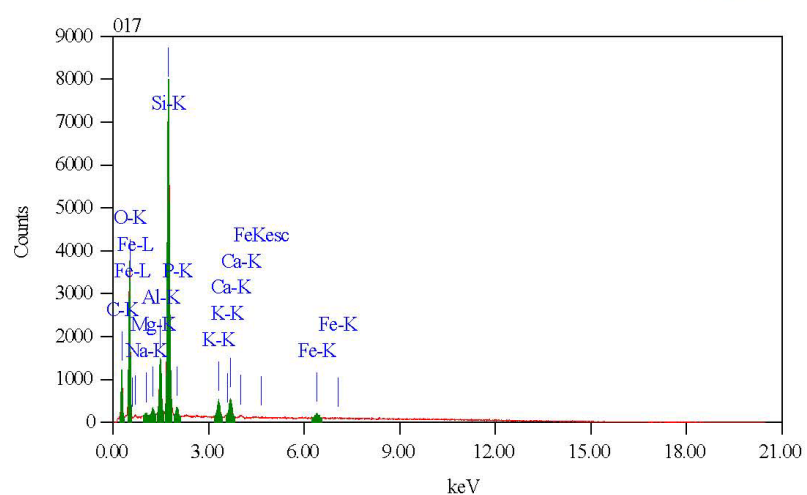
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.45 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0516

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	2.70	0.04	1.64				3.9133
C K	0.277	30.98	0.17	42.23				11.9210
Ca K	3.690	1.77	0.03	0.72				3.6448
Fe K	6.398	1.27	0.05	0.37				2.2139
K K	3.312	1.52	0.03	0.64				2.9824
Mg K	1.253	0.43	0.02	0.29				0.5181

Image002

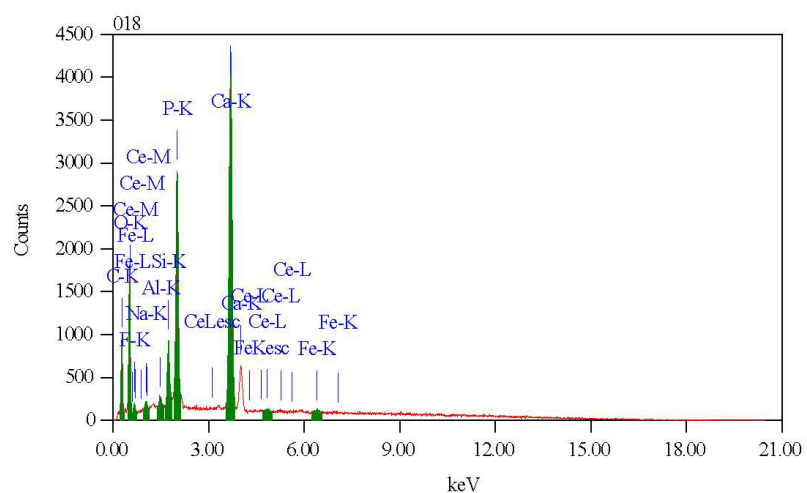
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

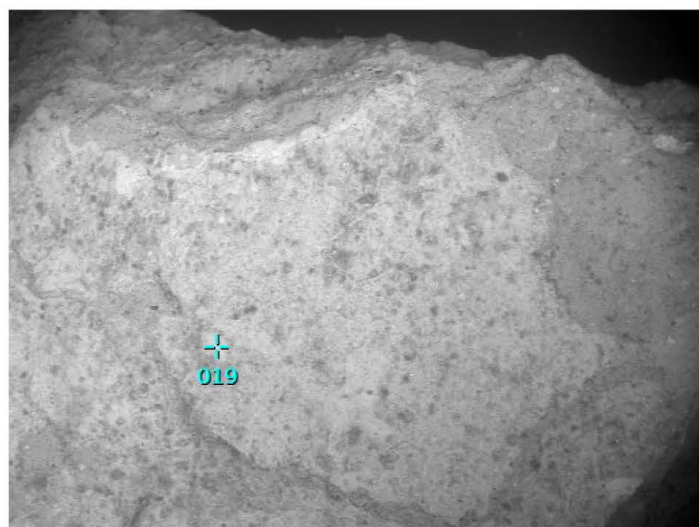
Real Time : 15.00 sec

Live Time : 13.53 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0354

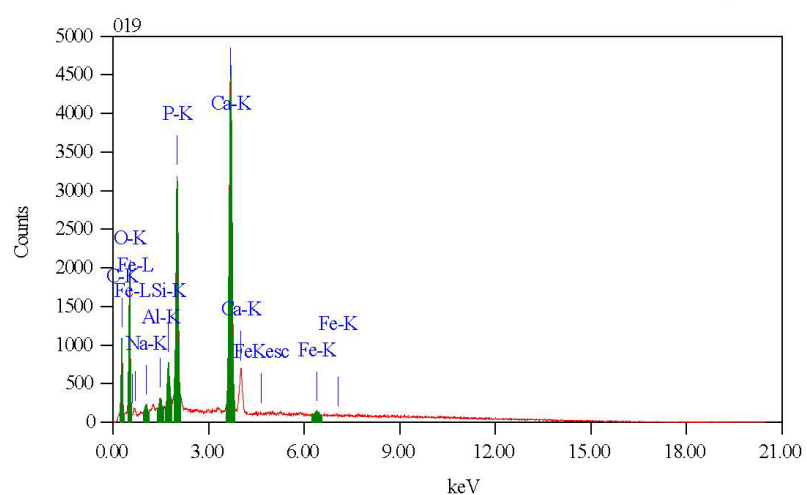
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.35	0.02	0.24				0.4183
C K	0.277	23.60	0.15	36.05				10.0695
Ca K	3.690	21.44	0.11	9.81				39.9638
Ce L	4.837	0.71	0.08	0.09				0.9862
F K	0.677	2.04	0.11	1.97				2.1632
Fe K	6.398	0.44	0.04	0.14				0.6551



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.45 sec

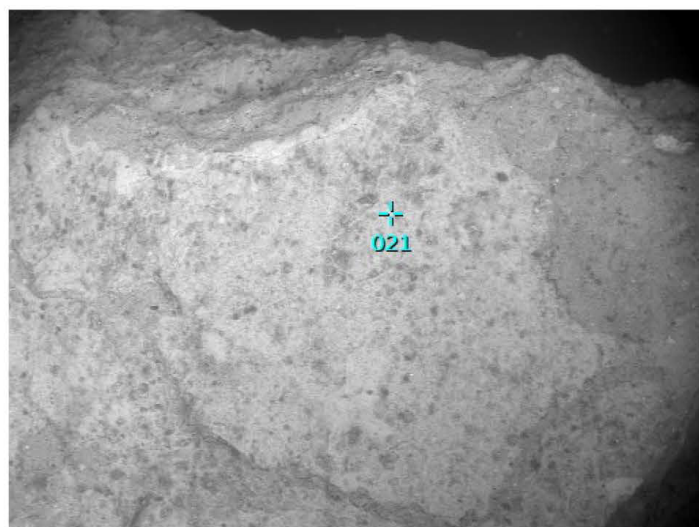
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0347

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.39	0.02	0.26				0.4681
C K	0.277	24.99	0.14	37.75				10.9412
Ca K	3.690	22.08	0.11	10.00				41.7278
Fe K	6.398	0.67	0.05	0.22				1.0265
Na K	1.041	0.53	0.03	0.41				0.5483

Image002

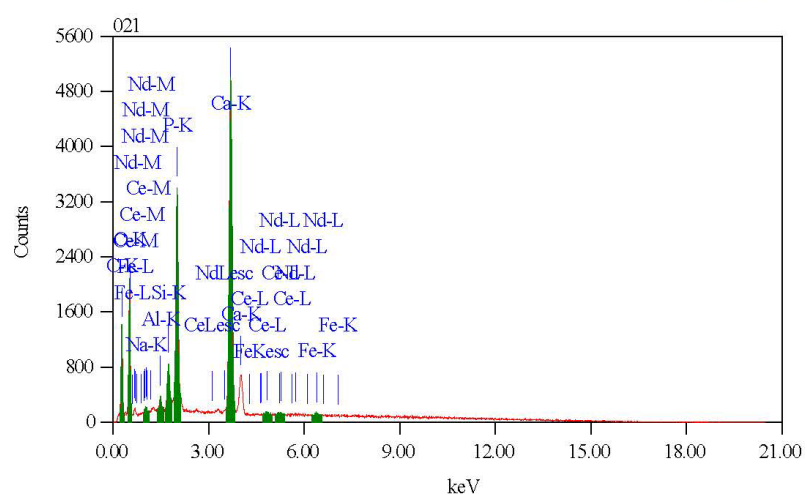
1/1



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.37 sec

ZAF Method Standardless Quantitative Analysis

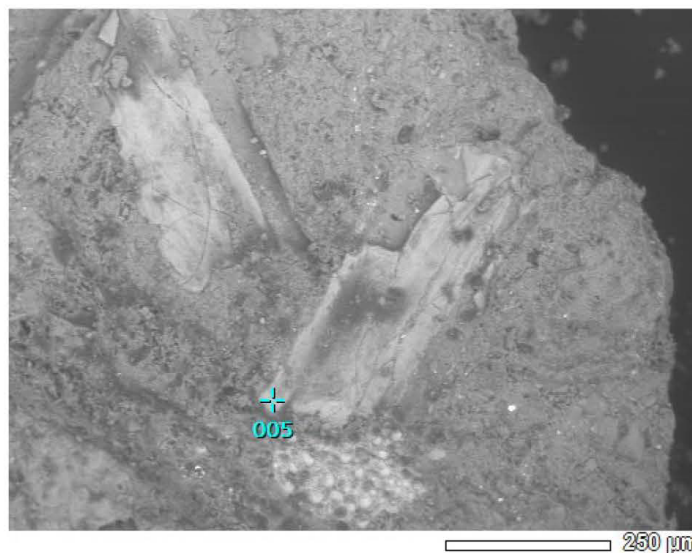
Fitting Coefficient : 0.0355

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.38	0.02	0.25				0.4653
C K	0.277	27.78	0.14	41.45				13.0684
Ca K	3.690	20.98	0.10	9.38				40.3924
Ce L	4.837	0.77	0.07	0.10				1.1029
Fe K	6.398	0.52	0.04	0.17				0.8023
Na K	1.041	0.34	0.03	0.27				0.3629

f. Scutate scale Sp3b:

Image000

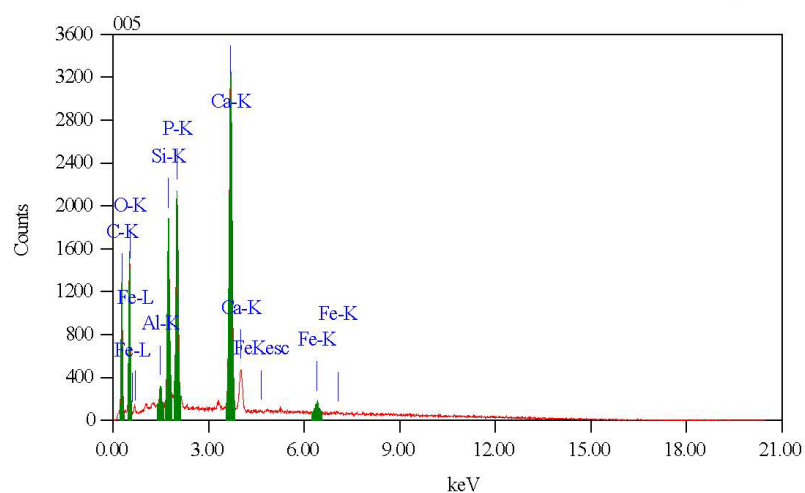
1/1



Title : IMG1

Instrument : IT300 (LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300 (LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.87 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0441

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.54	0.02	0.34				0.7292
C K	0.277	32.58	0.17	46.56				15.6900
Ca K	3.690	16.85	0.10	7.21				34.4808
Fe K	6.398	1.55	0.06	0.48				2.5690
O K	0.525	35.17	0.30	37.73				22.8260

JED-2300 AnalysisStation

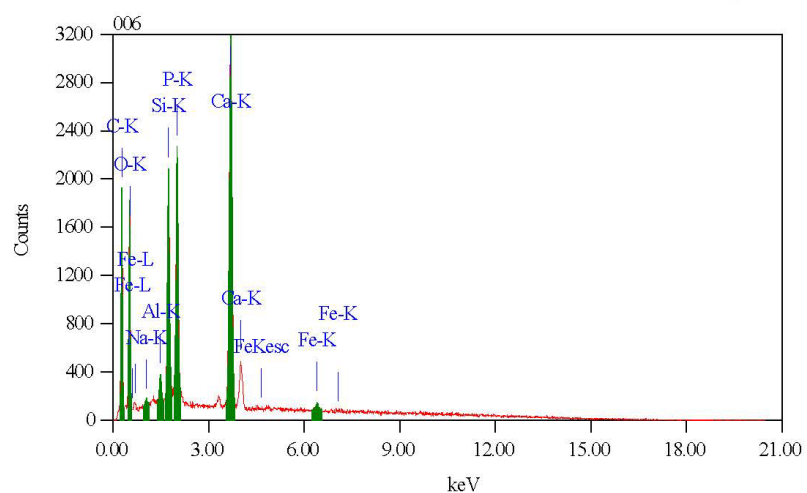
JEOL



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.68 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0397

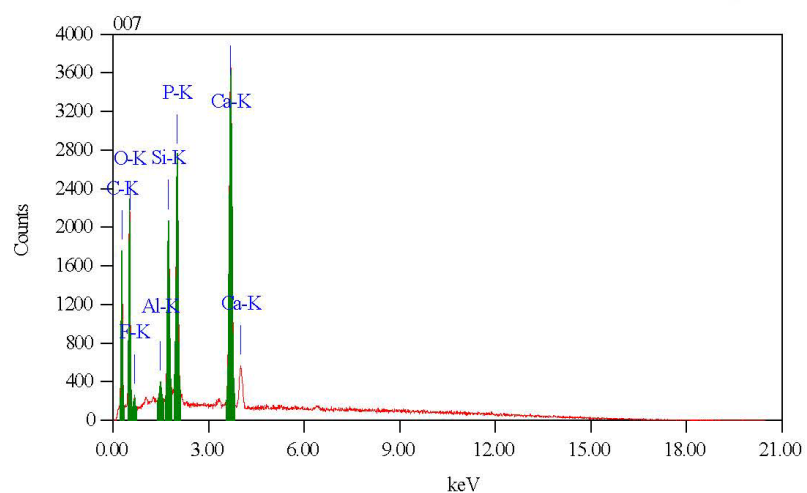
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.53	0.02	0.32				0.7744
C K	0.277	39.11	0.16	52.96				21.6843
Ca K	3.690	13.57	0.08	5.51				29.6502
Fe K	6.398	0.80	0.04	0.23				1.4154
Na K	1.041	0.27	0.02	0.19				0.3405



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.28 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0405

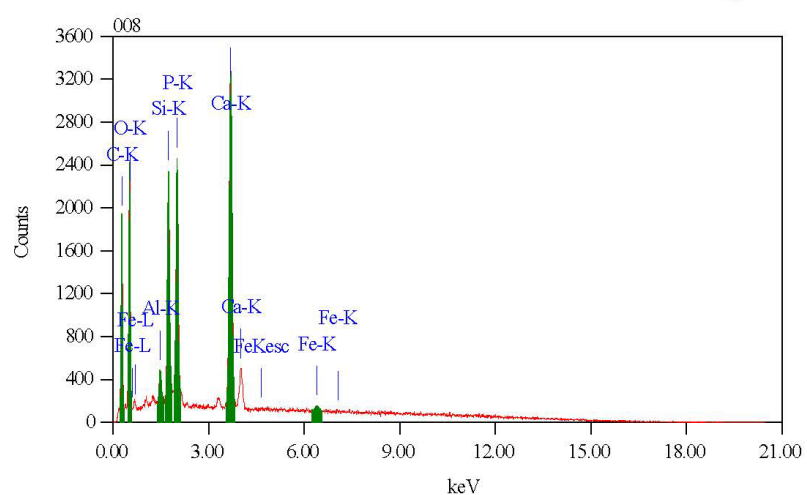
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.39	0.02	0.24				0.5412
C K	0.277	33.82	0.15	46.81				17.4017
Ca K	3.690	14.44	0.08	5.99				30.3987
F K	0.677	1.89	0.09	1.65				2.2975
O K	0.525	36.84	0.27	38.28				25.8851



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.42 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0443

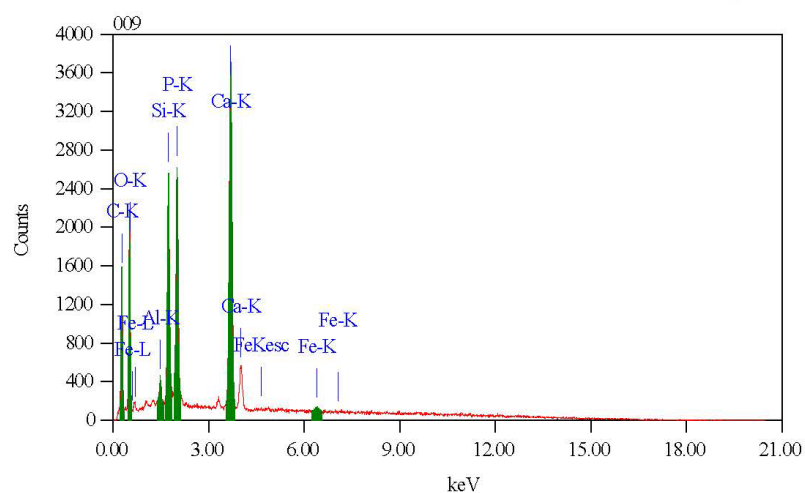
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.66	0.02	0.40				0.9391
C K	0.277	35.74	0.15	48.69				19.4007
Ca K	3.690	12.82	0.08	5.24				27.7399
Fe K	6.398	0.73	0.04	0.21				1.2762
O K	0.525	37.90	0.26	38.76				27.8467



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.48 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0420

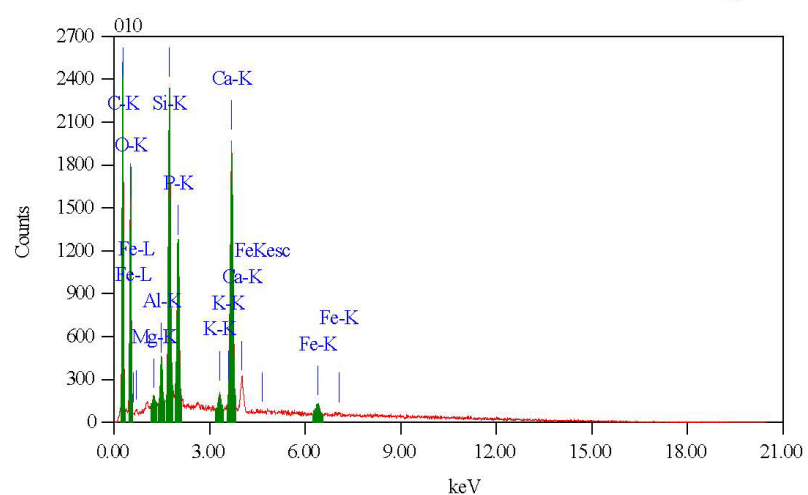
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.55	0.02	0.34				0.7623
C K	0.277	33.36	0.16	46.79				16.2182
Ca K	3.690	15.08	0.09	6.34				31.6097
Fe K	6.398	0.57	0.04	0.17				0.9683
O K	0.525	36.57	0.27	38.50				25.1479



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 14.00 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0429

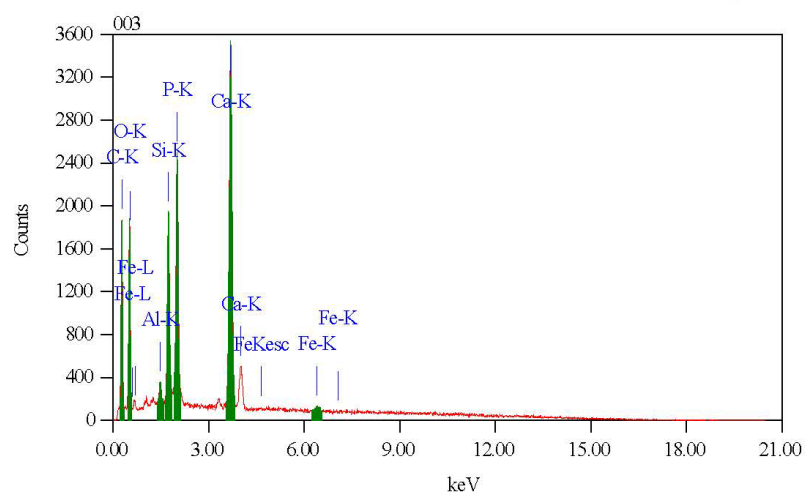
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.77	0.02	0.44				1.2212
C K	0.277	47.16	0.17	59.86				32.5045
Ca K	3.690	8.09	0.06	3.08				18.9798
Fe K	6.398	1.01	0.04	0.27				1.9138
K K	3.312	0.46	0.02	0.18				1.0451
Mg K	1.253	0.22	0.02	0.14				0.2831



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.59 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0406

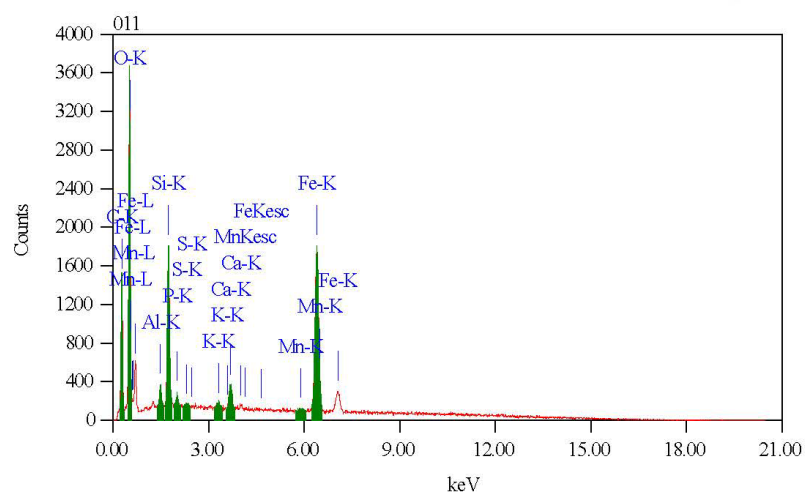
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.41	0.02	0.25				0.5853
C K	0.277	37.62	0.16	51.29				20.7031
Ca K	3.690	14.47	0.08	5.91				31.2326
Fe K	6.398	0.48	0.04	0.14				0.8293
O K	0.525	35.01	0.27	35.83				23.6634



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.67 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0462

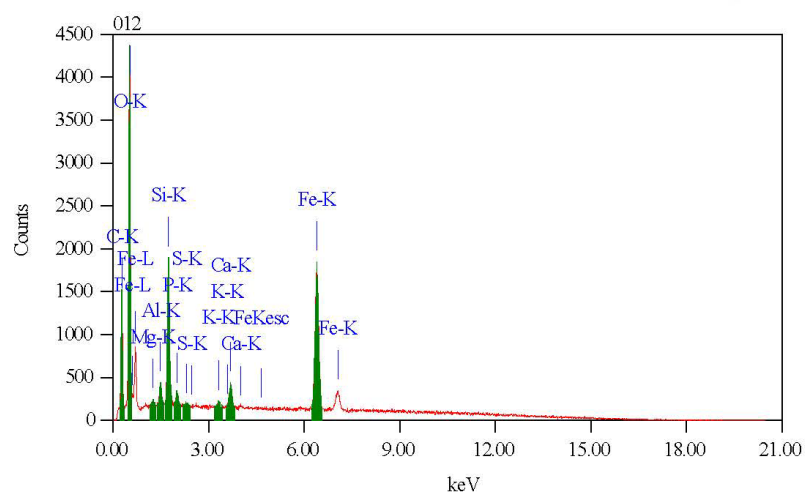
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.64	0.03	0.44				0.5996
C K	0.277	29.26	0.14	44.44				14.4773
Ca K	3.690	1.22	0.03	0.55				2.1329
Fe K	6.398	25.45	0.17	8.31				36.6172
K K	3.312	0.22	0.02	0.10				0.3675
Mn K	5.894	0.31	0.04	0.10				0.4325



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

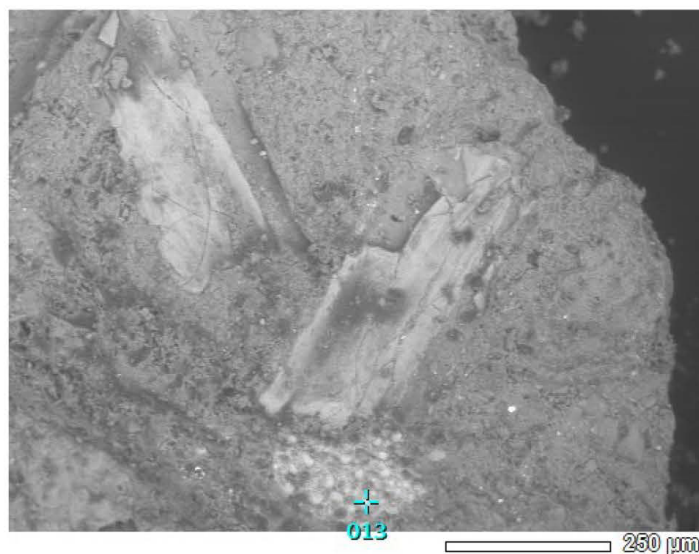
Real Time : 15.00 sec

Live Time : 13.34 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0503

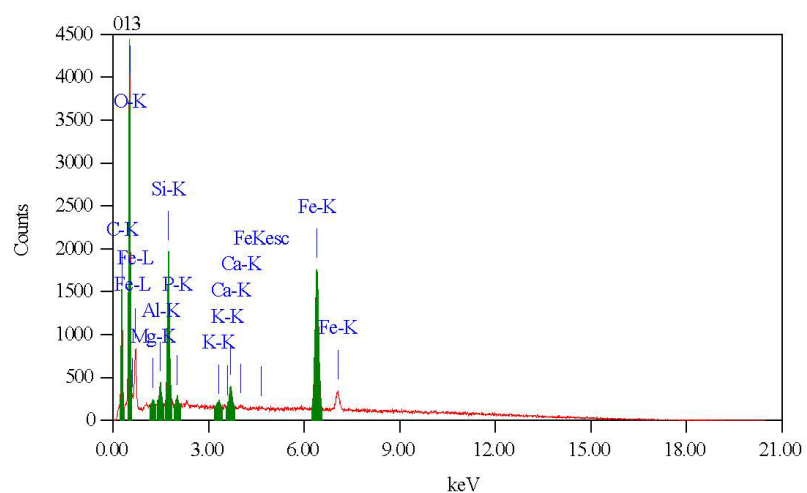
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.70	0.03	0.47				0.6396
C K	0.277	27.15	0.13	40.93				13.0843
Ca K	3.690	1.16	0.03	0.52				1.9786
Fe K	6.398	23.67	0.17	7.68				33.2060
K K	3.312	0.30	0.02	0.14				0.4896
Mg K	1.253	0.19	0.02	0.14				0.1343



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.34 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0531

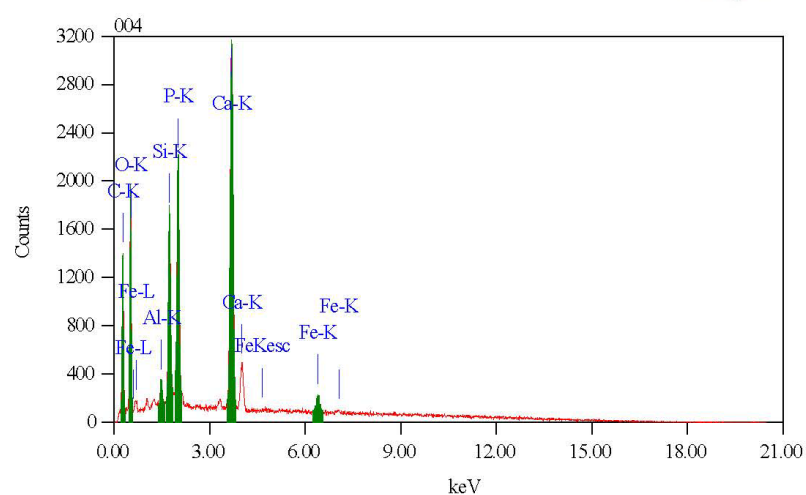
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.68	0.03	0.46				0.6254
C K	0.277	27.44	0.13	41.18				13.4234
Ca K	3.690	1.05	0.03	0.47				1.7984
Fe K	6.398	23.50	0.17	7.59				33.0024
K K	3.312	0.24	0.02	0.11				0.3908
Mg K	1.253	0.25	0.03	0.19				0.1776



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.67 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0392

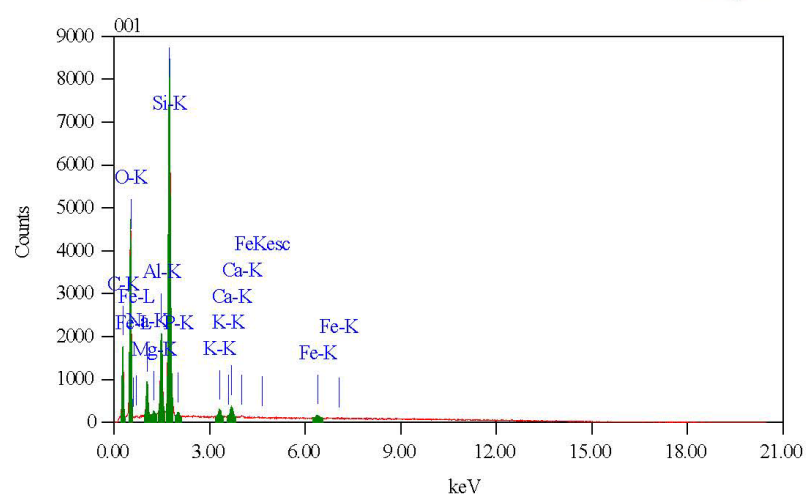
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	0.58	0.02	0.37				0.7830
C K	0.277	32.66	0.16	46.21				16.2515
Ca K	3.690	15.21	0.09	6.45				31.4241
Fe K	6.398	2.06	0.06	0.63				3.4536
O K	0.525	36.88	0.29	39.17				25.3747



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.38 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0553

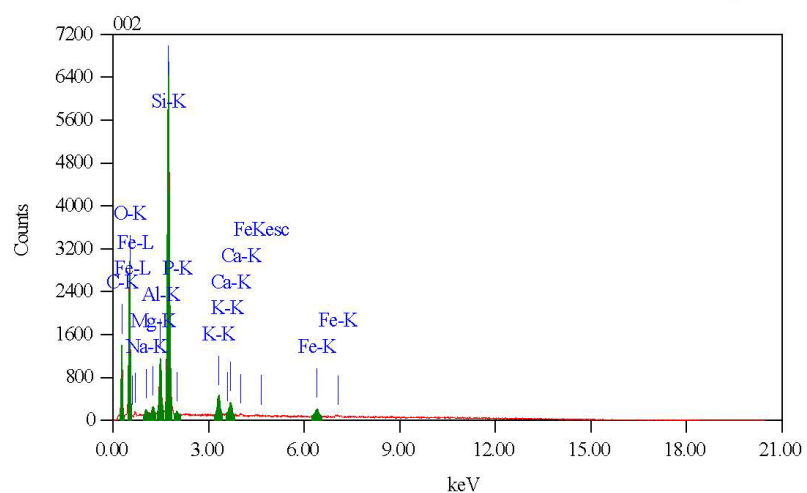
Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	3.20	0.03	1.88				4.7588
C K	0.277	34.41	0.15	45.39				15.0794
Ca K	3.690	0.80	0.02	0.32				1.7297
Fe K	6.398	0.71	0.03	0.20				1.2805
K K	3.312	0.57	0.02	0.23				1.1733
Mg K	1.253	0.18	0.01	0.12				0.2176



Title : IMG1

Instrument : IT300(LA)

Volt : 20.00 kV



Acquisition Parameter

Instrument : IT300(LA)

Acc. Voltage : 20.0 kV

Probe Current: 7.47500 nA

PHA mode : T3

Real Time : 15.00 sec

Live Time : 13.77 sec

ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0494

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
Al K	1.486	2.35	0.03	1.38				3.6188
C K	0.277	36.55	0.18	48.38				16.7231
Ca K	3.690	1.09	0.03	0.43				2.4014
Fe K	6.398	1.95	0.05	0.56				3.6148
K K	3.312	1.59	0.03	0.65				3.3561
Mg K	1.253	0.39	0.02	0.26				0.4976

Supplementary references:

- S1** Barrett, P. M., Butler, R. J., Wang, X. & Xu, X. Cranial anatomy of the iguanodontoid ornithopod *Jinzhousaurus yangi* from the Lower Cretaceous Yixian Formation of China. *Act. Palaeont. Pol.* **54**, 35–48 (2009).
- S2** Xu, X. et al. A large-sized basal ankylopollexian from East Asia, shedding light on early biogeographic history of Iguanodontia. *Sc. Bull.* **63 (9)**, 556–563 (2018).
- S3** Norman, D. B. On the ornithischians dinosaur *Iguanodon bernissartensis* of Bernissart (Belgium). *Mém. Inst. Roy. Sc. Nat. Belg.* **178**, 1-103 (1980)895775.
- S4** Norman, D. B. On Asian ornithopods (Dinosauria: Ornithischia). 3. A new species of iguanodontid dinosaur. *Zool. J. Linn. Soc.* **122**, 291-348 (1998).
- S5** Norman, D. B. On the anatomy of *Iguanodon atherfieldensis* (Ornithischia: Ornithopoda). *Bull. I.R.Sc.N.B., Sc. Terre* **56**, 281-372 (1986).
- S6** Taquet, P. 1976. Géologie et paléontologie du gisement de Gadoufaoua (Aptien du Niger). *Cah. Paléont. C.N.R.S.*, 1-191 (1976).
- S7** Galton, P. M. The cranial anatomy of *Dryosaurus*, a hypsilophodontid dinosaur from the Upper Jurassic of North America and East Africa, with a review of hypsilophodontids from the Upper Jurassic of North America. *Geol. Palaeont.* **17**, 207–243 (1983).
- S8** Lockwood, J. A. F., Martill, D. M. & Maidment, S. C. R. A new hadrosauriform dinosaur from the Wessex Formation, Wealden Group (Early Cretaceous), of the Isle of Wight, southern England. *J. Syst. Pal.* **19**, 847–888 (2021).
- S9** McDonald, A., Maidment, S. C. R., Barrett, P. M., You, H.-L. & Dodson, P. In *Hadrosaurs* (eds Eberth, D. A. & Evans, D. C.) 44-72 (Indiana University Press, 2014).
- S10** Ostrom, J. H. Cranial morphology of the hadrosaurian dinosaurs of North America. *Bull. Am. Mus. Nat. Hist.* **122**, 33-186 (1961).
- S11** Head, J. J. A new species of basal hadrosaurid (Dinosauria, Ornithischia) from the Cenomanian of Texas. *J. Vert. Paleont.* **28 (4)**, 718-738 (1998).
- S12** Norman, D. B. On Asian ornithopods (Dinosauria: Ornithischia). 4. *Probactrosaurus* Rozhdestvensky, 1966. *Zool. J. Linn. Soc.* **136**, 113-144 (2002).
- S13** You, H.-L., Ji, Q. J., Li, J & Li, Y. A new hadrosauroid dinosaur from the Mid-Cretaceous of Liaoning, China. *Act. Geol. Sin.* **77**, 148-154. (2003).

- S14** Weishampel, D. B., Horner, J. R. The Hadrosaurid dinosaurs from the Iren Dabasu Fauna (People's Republic of China, Late Cretaceous. *J. Vert. Paleont.* **6** (1), 38–45 (1985).
- S15** McDonald, A T., Espilez, E., Mampel, L., Kirkland, J. I. & Alcalá, L. An unusual new basal iguanodont (Dinosauria: Ornithopoda) from the Lower Cretaceous of Teruel, Spain". *Zootaxa* **3595**, 61–76 (2012).
- S16** Godefroit, P., Dong, Z.-M., Bultynck, P., Li, H. & Feng, L. 1998. New *Bactrosaurus* (Dinosauria: Hadrosauridae) material from Iren Dabasu (Inner Mongolia, P.R. China). *Bull. I.R.Sc.N.B., Sc. Terre* **68** (suppl.), 3-70 (1998).
- S17** Kobayashi, Y. & Azuma, Y. A new iguanodontian (Dinosauria: Ornithopoda) from the Lower Cretaceous Kitadani Formation of Fukui Prefecture, Japan. *J. Vert. Paleont.* **23**, 166-175 (2003).
- S18** Campione, N. E. & Evans, D. C. Cranial growth and variation in edmontosaurs (Dinosauria: Hadrosauridae): implications for latest Cretaceous megaherbivore diversity in North America. *PLoS ONE* **6**(9), e25186 (2011).
- S19** Galton, P. M. The ornithischian dinosaur *Hypsilophodon* from the Wealden of the Isle of Wight. *Bull. Br. Mus. (Nat. Hist.), Geol.* **25**, 1–152 (1974).
- S20** McDonald, A. T. Phylogeny of basal iguanodonts (Dinosauria: Ornithischia): an update. *PLoS ONE* **7** (5), e36745 (2012).
- S21** Weishampel, D. B., Norman, D. B. & Grigorescu, D. *Telmatosaurus transsylvanicus* from the Late Cretaceous of Romania: the most basal hadrosaurid dinosaur. *Palaeontology* **36**, 361–385 (1993).
- S22** Dalla Vecchia, F. M. *Tethyshadros insularis*, a new hadrosauroid dinosaur (Ornithischia) from the Upper Cretaceous of Italy. *J. Vert. Paleont.* **29**, 1100–1116 (2009).
- S23** Boyd, C. A. The cranial anatomy of the neornithischian dinosaur *Thescelosaurus neglectus*. *PeerJ* **2**, e669 (2014).
- S25** Weishampel, D. B., Jianu, C.-M., Csiki, Z. & Norman, D. B. Osteology and phylogeny of *Zalmoxes* (N. G.), an unusual euornithopod dinosaur from the latest Cretaceous of Romania. *J. Syst. Palaeont.* **1**, 65–123 (2003).
- S26** Ostrom, J. H. Stratigraphy and paleontology of the Cloverly Formation (Lower Cretaceous) of the Bighorn Basin area, Wyoming and Montana. *Bull. Peab. Mus. Nat. Hist.* **30**, 1–234 (1970).
- S27** Gilmore, C. W. Osteology of the Jurassic reptile *Camptosaurus*, with revision of the species of the genus and description of two new species. *Proc. US Nat. Mus.* **36**, 197–332 (1909).
- S28** Horner, J. R., Weishampel, D. B. & Forster, C.A. In *The Dinosauria 2nd edition* (eds Weishampel, D. B., Dodson, P. & Osmólska, H.) 438–463 (University of California Press, 2004).

- S29** Lockwood, J. A. F., Martill, D. M. & Maidment, S. C. R. *Comptonatus chasei*, a new iguanodontian dinosaur from the Lower Cretaceous Wessex Formation of the Isle of Wight, southern England. *J. Syst. Palaeont.* **22** (1), 2346573 (2024).
- S30** Tsogtbaatar, K., Weishampel, D. B., Evans, D. C. & Watabe, M. A new hadrosauroid (Dinosauria: Ornithopoda) from the Late Cretaceous Baynshire Formation of the Gobi Desert (Mongolia). *PLoS ONE* **14** (4): e0208480 (2019).
- S31** Head, J.J. A reanalysis of the phylogenetic position of *Eolambia caroljonesa* (Dinosauria, Iguanodontia). *J. Vert. Paleont.* **21** (2), 392–396 (2001).
- S32** Prieto-Marquez A. In *Horns and beaks, Ceratopsian and ornithopod dinosaurs* (ed Carpenter, K.) 91-115 (Indiana University Press, 2007).
- S33** Parks, W. A. The osteology of the trachodont dinosaur *Kritosaurus incurvimanus*. *Univ. Tor. Stud., Geol. Ser.* **11**, 1-74 (1920).
- S34** Brown, B. *Corythosaurus casuarius*: skeleton, musculature and epidermis. *Am. Mus. Nat. Hist. Bull.* **38**, 709–715 (1916).
- S35** Adams, J. S. & Organ, C. L. Histologic determination of ontogenetic patterns and processes in hadrosaurian ossified tendons. *J. Vert. Paleont.* **25**, 614-622 (2005).
- S36** Evans, D. C. & Reisz, R. R. Anatomy and relationships of *Lambeosaurus magnicristatus*, a crested hadrosaurid dinosaur (Ornithischia) from the Dinosaur Park Formation. Alberta. *J. Vert. Paleont.* **27**, 373–393 (2007).
- S37** Taquet, P. & Russell, D.A. A massively-constructed iguanodont from Gadoufaoua, Lower Cretaceous of Niger. *Ann. Paléont.* **85**, 85–96 (1999).
- S38** Xu, X., Zhao, X.-Y., Lü, J.-C., Huang, W.-B. & Dong, Z.-M. A new iguanodontian from the Sangping Formation of Neixiang, Henan and its stratigraphical implications. *Vert. PalAs.* **38**, 176–191 (2000).
- S39** McDonald, A. T., Bird, J., Kirkland, J. I. & Dodson, P. Osteology of the basal hadrosauroid *Eolambia caroljonesa* (Dinosauria: Ornithopoda) from the Cedar Mountain Formation of Utah. *PLoS ONE* **7** (10), e45712 (2012).
- S40** Winkler, D. A., Murry, P. A. & Jacobs, L. L. A new species of *Tenontosaurus* (Dinosauria: Ornithopoda) from the Early Cretaceous of Texas. *J. Vert. Paleont.* **17**, 330–348 (1997).

- S41** Lull, R. S. & Wright, N. E. Hadrosaurian dinosaurs of North America. *Geol. Soc. Am. Sp. Pap.* **40**, 1-242 (1942).
- S42** Norman, D. B. In *The Dinosauria 2nd edition* (eds Weishampel, D. B., Dodson, P. & Osmólska, H.) 413–437 (University of California Press, 2004).
- S43** Horner, J. R. The ontogenetic predictability of hadrosaur crania. *J. Vert. Paleont.* **9(3)**, 25A (1989).
- S44** Horner, J. R. & Currie, P. J. Embryonic and neonatal morphology and ontogeny of a new species of *Hypacrosaurus* (Ornithischia, Lambeosauridae) from Montana and Alberta. In *Dinosaur Eggs and Babies* (eds Carpenter, K., Hirsch, K. F. & Horner, J. R.) 312–336 (Cambridge University Press, 1994).
- S45** Dilkes, D. W. An ontogenetic perspective on locomotion in the Late Cretaceous dinosaur *Maiaasaura peeblesorum* (Ornithischia: Hadrosauridae). *Can. J. Earth Sci.* **38**, 1205-1227 (2001).
- S46** Zheng, W., Jin, X., Shibata, M., & Azuma, Y. An early juvenile specimen of *Bolong yixianensis* (Ornithopoda: Iguanodontia) from the Lower Cretaceous of Ningcheng County, Nei Mongol, China. *Hist. Biol.* **26(2)**, 236–251 (2013).
- S47** Verdú, F. J., Royo-Torres, R., Cobos, A. & Alcalá, L. Perinates of a new species of *Iguanodon* (Ornithischia: Ornithopoda) from the lower Barremian of Galve (Teruel, Spain)". *Cret. Res.* **56**, 250–264 (2015).
- S48** Fuentes Vidarte, C., Mejjide Calvo, M., Mejjide Fuente, R. & Mejjide Fuentes, M. Un nuevo dinosaurio estiracosterno (Ornithopoda: Ankylopollexia) del Cretácico Inferior de España). *Span. J. Palaeont.* **31**, 407–446. (2016).
- S49** Gasulla, J. M., Escaso, F., Narváez, I., Ortega, F., & Sanz, J. L. A new sail-backed styracosternan (Dinosauria: Ornithopoda) from the Early Cretaceous of Morella, Spain. *PLoS ONE* **10(12)**, e0144167 (2015).
- S50** Santos-Cubedo, A., de Santisteban, C., Poza, B. & Meseguer, S. A new styracosternan hadrosauroid (Dinosauria: Ornithischia) from the Early Cretaceous of Portell, Spain. *PLoS ONE* **16(7)**, e0253599 (2021).
- S51** Bonsor, J. A., Lockwood, J. A. F., Vasco Leite, J., Scott-Murray, A. & Maidment, S. C. R. The osteology of the holotype of the British iguanodontian dinosaur *Mantellisaurus atherfieldensis*. *Monogr. Palaeont. Soc.* **177(665)**, 1–63 (2023).

- S52** Lockwood, J. A. F., Martill, D. M. & Maidment, S. C. R. The origins of neural spine elongation in iguanodontian dinosaurs and the osteology of a new sail-back styracosternan (Dinosauria, Ornithischia) from the Lower Cretaceous Wealden Group of England. *Pap. Palaeont.* **11(4)**, e70034 (2025).
- S53** Dollo, L. Première note sur les dinosauriens de Bernissart. *Bull. Mus. Roy. Hist. Nat. Belg.* **1**, 55-80 (1882).
- S54** Paul, G. S. A revised taxonomy of the iguanodont dinosaur genera and species. *Cret. Res.* **29**, 192-216 (2008).
- S55** Norman D. B. On the taxonomy and diversity of Wealden iguanodontian dinosaurs (Ornithischia: Ornithopoda). *Rev. Paléobiology*, **32**, 385–404. (2013).
- S56** Lehman, T. M. Late Cretaceous dinosaur provinciality. In *Mesozoic Vertebrate Life* (eds Tanke, D. H. & Carpenter, K.) 310-328 (Indiana University Press, 2001).
- S57** Sampson, S. D. *et al.* New horned dinosaurs from Utah provide evidence for intracontinental dinosaur endemism. *PLoS ONE* **5(9)**, e12292 (2010).
- S58** Ibiricu, L. M. *et al.* New hadrosaurid (Dinosauria: Ornithopoda) fossils from the uppermost Cretaceous of central Patagonia and the influence of paleoenvironment on South American hadrosaur distribution. *J. South Amer. Earth Sci.* **110**, 103369 (2021).
- S59** Ryan, M. J. & Evans, D. C. Ornithischian dinosaurs. In *Dinosaur Provincial Park: a spectacular ancient ecosystem revealed* (eds Currie, P. J. & Koppelhus, E. B.) 312–348 (Indiana University Press, 2005).
- S60** Mallon, J. C., Evans, D. C., Ryan, M. J. & Anderson, J. S. Megaherbivorous dinosaur turnover in the Dinosaur Park Formation (upper Campanian) of Alberta, Canada. *Palaeogeog., Palaeoclim., Palaeoecol.* **350**, 124–138 (2012).
- S61** Lowi-Merri, T. M. & Evans, D. C. Cranial variation in *Gryposaurus* and biostratigraphy of hadrosaurines (Ornithischia: Hadrosauridae) from the Dinosaur Park Formation of Alberta, Canada. *Can. J. Earth Sci.* **57(6)**, 765–779 (2020).
- S62** Eberth, D. A. *et al.* Dinosaur biostratigraphy of the Edmonton Group (Upper Cretaceous), Alberta, Canada: evidence for climate influence. *Can. J. Earth Sci.* **50**, 701–726 (2013).

- S63** Godefroit, P., Bolotsky, Y. L. & Bolotsky, I. Y. Osteology and relationships of *Olorotitan arharensis*, a hollow-crested hadrosaurids dinosaur from the latest Cretaceous of Far Eastern Russia. *Acta Palaeont. Pol.* **57**, 527–560 (2012).
- S64** Godefroit, P., Bolotsky, Y. L. & Lauters, P. A new saurolophine dinosaur from the latest Cretaceous of Far Eastern Russia. *PLoS ONE* **7(5)**, e36849 (2012).