##### Appendix A.1: Supplementary online Material

**Analytical methods**

Whole-rock major and trace element analyses were performed by fusion-dissolution sample decomposition and inductively coupled plasma mass spectrometry techniques (ICP-MS) at the SGIker-Geochronology and Isotope Geochemistry Facility Spain following procedures adapted from García de Madinabeitia et al. (2008). Major element compositions of minerals were determined on a Cameca SX100 electron microprobe at the Laboratoire Magmas & Volcans (LMV) in Clermont-Ferrand, France. Operating conditions were 15 kV accelerating voltage and 15 nA focused beam for minerals. Synthetic and natural minerals standards were used for calibration. with counting time set at 10 s for all elements. Fe3**+**/Fe2**+** and H2O contents in biotite and amphibole were estimated by charge balance criteria and regression methods (cf. Droop. 1987; Li et al.. 2020a. 2020b). An automated VG 54E thermal ionization mass spectrometer in the double collection mode was used at the LMV for Nd isotope composition and Sm-Nd concentration measurements by isotope dilution. A mixed 149Sm-150Nd tracer was used and the procedures for chemical separation and instrumental analysis are essentially similar to those described by Pin and Santos Zalduegui (1997). U-Pb analyses were performed also by isotope dilution–thermal ionization mass spectrometry at the LMV on the least magnetic mechanically abraded and crack-free zircon grains. Zircon dissolution, chemical separation of U and Pb, and isotope analyses were carried out according to methods described by Paquette et al. (1997). The U and Pb isotopes were analysed on a Fisons VG Sector 54-30 mass spectrometer in multicollector static mode. Initial common Pb is determined for each fraction using the Stacey and Kramers (1975) two-step model. Concordia graphs and ages were calculated using Isoplot Ex. 4.15 (Ludwig. 2001) and IsoplotR (Vermeesch. 2018). using actualized decay constants and errors: λ238U= 0.155125 ± 0.00016 Gyr-1 (Jaffey et al.. 1971); λ235U= 0.98531 ± 0.00012 Myr-1 (Schoene et al.. 2006; Mattinson. 2010. 2011; Hiess et al.. 2012) and 238U/235U natural ratio is 137.818 ± 0.005 (Hiess et al.. 2012). Ages and graphs in Figs. 8 to 10 show the uncertainty associated with the decay constants and are given at the 2σ or 95% confidence interval.

**References**

Droop, G.T.R., 1987, A general equation for estimating Fe3**+** concentrations in ferromagnesian silicates and oxides from microprobe analyses using stoichiometric criteria: Mineralogical Magazine, v. 51, p. 431-435. <https://doi.org/10.1180/minmag.1987.051.361.10>

García de Madinabeitia, S., Sánchez Lorda, M.E., and Gil Ibarguchi, J.I., 2008, Simultaneous determination of major to ultratrace elements in geological samples by fusion-dissolution and inductively coupled plasma mass spectrometry techniques: Analytica Chimica Acta, v. 625, p. 117-130. <https://doi.org/10.1016/j.aca.2008.07.024>

Jaffey, A.H., Flynn. K.F., Glendenin. L.E., Bentley. W.C., and Essling. A.M., 1971, Precision measurement of the half-lives and specific activities of 235U and 238U: Physical Review C, v. 4, p. 1889–1906. <https://doi.org/10.1103/PhysRevC.4.1889>

Hiess, J., Condon, D. J., McLean, N., and Noble, S. R., 2012, 238U/235U Systematics in Terrestrial Uranium-Bearing Minerals: Science, v. 335(6076), p. 1610. <https://doi.org/10.1126/science.1215507>

Li, X., Zhang, C., Behrens, H., and Holtz, F., 2020a, Calculating biotite formula from electron microprobe analysis data using a machine learning method based on principal components regression: Lithos, v. 356-357, 105371. <https://doi.org/10.1016/j.lithos.2020.105371>

Li, X., Zhang, C., Behrens, H., and Holtz, F., 2020b, Calculating amphibole formula from electron microprobe analysis data using a machine learning method based on principal components regression: Lithos, v. 362-363, 105469. <https://doi.org/10.1016/j.lithos.2020.105469>

Ludwig, K.R., 2001, Users Manual for Isoplot/Ex rev. 2.49. A Geochronological Toolkit for Microsoft Excel.

Mattinson, J.M., 2010, Analysis of the relative decay constants of 235U and 238U by multi-step CA-TIMS measurements of closed-system natural zircon samples: Chemical Geology, v. 275, p. 186–198. <https://doi.org/10.1016/j.chemgeo.2010.05.007>

Mattinson, J. M., 2011, Extending the Krogh legacy: development of the CA–TIMS method for zircon U–Pb geochronology: Canadian Journal of Earth Sciences, v. 48, p. 95-105. <https://doi.org/10.1139/E10-023>

Paquette, J.L., Gleizes, G., Leblanc, D., and Bouchez, J.L., 1997, Le granite de Bassiés (Pyrénées): un pluton syntectonique d’âge Westphalien. Géochronologie U–Pb sur zircons: Comptes Rendus de l’Académie des Sciences, v. 324, p. 387–392.

Pin, C., and Santos Zalduegui, J.F., 1997, Sequential separation of light rare-earth elements. thorium and uranium by miniaturized chromatography; application to isotopic analyses of silicate rocks: Analytica Chimica Acta, v. 339, p. 79–89. <https://doi.org/10.1016/S0003-2670(96)00499-0>

Schoene, B., Crowley, J.L., Condon, D.J., Schmitz, M.D., and Bowring, S.A., 2006, Reassessing the uranium decay constants for geochronology using ID-TIMS U–Pb data: Geochimica and Cosmochimica Acta, v. 70, p. 426-445. <https://doi.org/10.1016/j.gca.2005.09.007>

Stacey, J.S., and Kramers, J.D., 1975, Approximation of Terrestrial Lead Isotope Evolution by a 2-Stage Model: Earth and Planetary Science Letters, v. 26, p. 207-221. <https://doi.org/10.1016/0012-821X(75)90088-6>

Vermeesch, P., 2018, IsoplotR: a free and open toolbox for geochronology: Geoscience Frontiers, v. 9, p. 1479-1493. <https://doi.org/10.1016/j.gsf.2018.04.001>