4 Age Analysis and Biostratigraphic Correlation

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In order to decipher brachiopod diversity and body-size changes in relation to varied palaeobathymetry and time, the stratigraphic divisions in each section and age correlation among sections are essential for the study. Details of each section are thus given below.

At Hushan, the cephalopod *Lopingoceras* sp. was found in Bed 89 of the section, ammonoids *Pernodoceras* sp. and *Pleuronodoceras* sp. were found in Bed 83 in the upper part of the Talung Formation, and the bivalve *Hunanopecten exilis* was found in Beds 73 and 88 (He et al. 2011). The ammonoid *Ophiceras* sp. was found in Bed 94 of the basal part of the Lower Chinglung Formation at Hushan (Fig. 3.1; He et al. 2011). According to the study of the Permian–Triassic biostratigraphy, *Lopingoceras* sp. is common within the Upper Permian of South China (Zhao et al. 1978). Both *Pernodoceras* sp. and *Pleuronodoceras* sp. from the upper Talung Formation are regarded as index fossils of the *Pseudotirolites–Pleuronodoceras* Zone of late Changhsingian age (Zhao et al. 1978; Yang et al. 1987). *Hunanopecten exilis* is typical for the Late Permian (Yin 1985). The genus *Ophiceras* is typical for the Induan (earliest Triassic) (Guo 1982). Therefore, the upper Talung Formation is assigned approximately to the late Changhsingian (latest Permian) while the basal part of the Lower Chinglung Formation can be considered to belong to the Induan (earliest Triassic) (Fig. 3.1; He et al. 2011).

At Majiashan, the ammonoid *Konglingites* sp. was found from Bed 1, *Tapashanites* sp. from Bed 3 to the basal part (20 cm) of Bed 10, *Pseudotirolites* spp. and *Rododiscoceras* spp. from the lower part of Bed 10 to Bed 16 and *Ophiceras* sp. from Bed 20 (Fig. 3.1; see He et al. 2008). *Konglingites* is the index fossil of the *Konglingites* Zone and typical of the Wuchiapingian (Zhao et al. 1978; Yang et al. 1987). *Tapashanites* is the index fossil of the *Tapashanites* Zone and typical for the early Changhsingian (Zhao et al. 1978; Yang et al.

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1987). *Pseudotirolites* and *Rododiscoceras* are both index fossils of the *Pseudotirolites–Rododiscoceras* Zone and typical for the late Changhsingian (Zhao et al. 1978; Yang et al. 1987). As mentioned above, *Ophiceras* is typical for the earliest Triassic. Beds 3–16, therefore, are assigned to the Changhsingian, and Bed 20 to the earliest Triassic (Fig. 3.1; He et al. 2015). Although no index fossils characteristic of the PTB has been found from Beds 17–19, we place the PTB in the middle of Bed 19, based on its similarity and equivalence to the Permian–Triassic Boundary Stratigraphic Set (PTBS) (see Peng et al. 2001 for description and correlation of PTBS), which has been precisely matched with the same set at Meishan (Fig. 3.1). It is because this correlation, Bed 17 at Majiashan, a 4-cm interval of pale volcanic claystones, can be matched to the 'White clay' of Bed 25 of the Meishan section. Likewise, Bed 18 at Majiashan, comprised of dark green calcareous mudstones, can be correlated to the 'Black clay' of Bed 26 of Meishan, and Bed 19 (gray limestones) correlated to the limestones of Bed 27 at Meishan.

At Rencunping, the *Clarkina yini* Zone has been found from Bed 22 to the middle part of Bed 23d (He et al. 2015). Conodont *Clarkina meishanensis* first appears in the upper part of Bed 23d (He et al. 2015). These suggest that Bed 22 to the middle part of Bed 23d are equivalent to the top part of Bed 22 to Bed 24d at Meishan (as constrained by the *C. yini* Zone), and the upper part of Bed 23d is equivalent to the base of Bed 24e at Meishan (He et al. 2015). Additionally, ammonoids of the *Sinoceltites* Zone (equivalent to the *Tapashanites* Zone) and of the *Pseudotirolites–Rotodiscoceras* Zone have been found, respectively, from Bed 18 to the lower part of Bed 20 and from the upper part of Bed 20 to Bed 24 at Rencunping (Fig. 3.1; see Zhang et al. 2009). Ammonoids of the *Sinoceltites* and *Pseudotirolites–Rotodiscoceras* Zones, respectively, suggest ages of early and late Changhsingian (Yang et al. 1987). Ammonoids of the *Ophiceras* Zone, typical for the Induan (Yin et al. 2001), have been found in the upper part of Bed 27 at Rencunping (Fig. 3.1; see Zhang et al. 2009). Beds 18–24 at Rencunping, therefore, can be reliably assigned to the Changhsingian, and the upper part of Bed 27 to Bed 29 to the earliest Triassic, with the PTB placed in the middle of Bed 27, as defined by the first appearance of *Ophiceras* sp. (Fig. 3.1).

At Xinmin, ammonoids *Pseudotirolites* spp., *Rotodiscoceras* sp., and *Pleuronodoceras* sp. (index fossils of *Pseudotirolites–Rotodiscoceras* Zone) were commonly found from Bed 1 to the lower part of Bed 5, suggesting that the Talung Formation is of late Changhsingian in age. The ammonoid *Ophiceras* sp. was found in Bed 6 and thus indicates that the basal part of the Daye Formation should be assigned to the Induan (earliest Triassic). Conodont *Hindeodus parvus* was found in the middle part of Bed 5, signaling the base of the Triassic at this level (Fig. 3.1; see Zhang et al. 2014).

At Duanshan, ammonoids *Pseudotirolites* spp., *Huananoceras* sp. and *Xenodiscus* sp. were commonly found from the Talung Formation. At Kejiao (close to Duanshan), ammonoids *Rotodiscoceras* spp. and *Pleuronodoceras* spp. occur abundantly in the Talung Formation. These elements suggest the presence of the *Pseudotirolites–Rotodiscoceras* Zone in the Talung Formation, indicating a late Changhsingian age (Fig. 3.1; see Zhang and He 2009).

At Shaiwa, bivalves *Hunanopecten exilis* and *Claraia primitiva* were found from the Fourth Member of the Shaiwa Group (Yang et al. 2001) and suggest the presence of the *Hunanopecten exilis–Claraia primitiva* Zone (Fig. 3.1). This bivalve zone is equivalent to the bivalve *Hunanopecten exilis* Assemblage of Yin (1985), the latter being typical for the Changhsingian (Yin 1985). Therefore, the Fourth Member of the Shaiwa Group is approximately of Changhsingian (Fig. 3.1; see He et al. 2014).

At Xiejiaping, the ammonoid *Pleuronodoceras* sp. was found in the upper part of the Talung Formation and *Ophiceras* sp. was found in the basal part (Bed 27) of the Daye Formation. Additionally, the Late Permian ammonoid *Huananoceras* sp. and brachiopod *Fusichonetes pygmaea* were found in the upper Talung Formation. These lines of evidence suggest that the upper Talung Formation (Beds 17–26) at Xiejiaping approximately should be assigned to

the late Changhsingian (Fig. 3.2; see He et al. 2014). The ammonoid *Sanyangites* sp. and *Konglingites* sp., both typical for the Wuchiapingian (Zhao et al. 1978; Yang et al. 1987), were found in the lower part of the Talung Formation (Beds 6–9), suggesting a Wuchiapingian age for these beds (Fig. 3.2).

At Dengcaoba, the ammonoid *Pseudotirolites* sp. and brachiopod *Paracrurithyris pygmaea* were found in the upper Talung Formation (Beds 34–36) and both elements are typical for the Changhsingian (Zhao et al. 1978; Yang et al. 1987; Xu and Grant 1994). The Late Permian ammonoid *Huananoceras* sp. was commonly found in the lower Talung Formation. Therefore, the upper Talung Formaton (Beds 34–36) is assigned to the Changhsingian and the lower Talung Formation (Beds 32–33) approximately to the Late Permian (or Wuchiapingian to early? Changhsingian) (Fig. 3.2; see He et al. 2014). The ammonoid *Lytophiceras* sp. was found in Bed 37 of the basal Daye Formation, indicating Bed 37 should be assigned to the Induan (Fig. 3.2).

At Shangname, ammonoids *Pseudotirolites* sp. and *Ophiceras* sp. were respectively found in Bed 2 (Talung Formation) and basal part of Bed 3 (Luolou Formation), suggesting a Changhsingian age for the former and Induan for the latter although these two beds are in fault contact (Fig. 3.2; see He et al. 2014).

At Dongpan, ammonoids *Pseudotirolites* sp., *Rotodiscoceras* sp., *Pernodoceras* sp. and *Dushanoceras* sp., which have been regarded as index fossils of the *Pseudotirolites*–*Rotodiscoceras* Zone, were commonly found in the Talung Formation (Bu et al. 2006). Radiolarian *Albaillella yaoi*, typical for the late Changhsingian (Wu et al. 2010; Zhang et al. 2017), was found in Beds 2–6 in the Talung Formation. The ammonoid *Ophiceras* sp. and bivalve *Claraia wangi* were commonly recorded in the basal part of the Luolou Formation (Bu et al. 2006; He et al. 2007; Yang et al. 2015). Therefore, the Talung Formation should be assigned to the late Changhsingian while the basal Luolou Formation to the Induan (Fig. 3.2).

At Paibi and Liuqiao, radiolarians *Albaillella triangularis* and *A. yaoi* Zones, both of which are equivalent to the *Neoalbaillella optima* Zone and typical for the late Changhsingian (Wu et al. 2010; Zhang et al. 2017), were found in the Talung Formation, suggesting a late Changhsingian age for this formation at Paibi and Liuqiao (Fig. 3.2).

At Huangzhishan, conodonts *Clarkina yini* and *C. meishanensis* Zones were respectively found in the top part of the Changhsing Formation (Beds 9–17) and the basal part of the Yinkeng Formation (Beds 18–36). *Hindeodus parvus* Zone (in Beds 37–42), together with *Ophiceras* sp. (in Bed 43 and upwards), was found in the lower Yinkeng Formation (Fig. 3.3; Chen et al. 2008; He et al. 2015). Therefore, the PTB has been defined at the horizon between Beds 36 and 37 (Fig. 3.3).

At Zhongzhai, the abundant presence of brachiopod *Fusichonetes pygmaea* in Beds 4–27 of the section, typical for the Changhsingian in South China (Shen and Archbold 2002; Zhang et al. 2013), suggests these intervals should have been assigned to the Changhsingian. The U–Pb age in Bed 29 of the section is of 252.24 ± 0.13 Ma and basically equivalent to the calibrated PTB age of 252.17 ± 0.06 Ma in Bed 27c at the GSSP section of Meishan (Shen et al. 2011; Zhang et al. 2014), thus indicating that the PTB is between Beds 29 and 30 (Fig. 3.3).

At Daoduishan, conodonts *Clarkina changxingensis*, *C. yini* and *C. meishanensis* Zones were respectively found in Bed 14 to base of Bed 21, upper part of Bed 21 to Bed 24b and Beds 24c to 26 of the Changhsing Formation (Fig. 3.3; see He et al. 2017). *Hindeodus parvus* was found in the middle of Bed 27 and *Ophiceras* sp. was found in Bed 29 (Fig. 3.3; see He et al. 2017). Therefore, the PTB has been placed in the middle of Bed 27 at Daoduishan (Fig. 3.3).

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