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3D Structure, Evolution, and Geodynamic Model of the Neoproterozoic Rift Basins in Southwestern Sichuan Basin, South China

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Post-cratonization rifting has emerged as a prominent research focus in structural geology due to its association with significant hydrocarbon accumulations. Such rift systems are extensively developed within and along the margins of cratonic regions during the Mesoproterozoic to Neoproterozoic, notably in areas such as the Siberian Craton, Australian Craton, and North American Craton. The genesis of these rift systems is typically attributed to extensional tectonic regimes that evolved during the post-orogenic reconfiguration of cratonic lithosphere. These systems represent critical tectono-sedimentary processes that influence crustal thinning, fault block development, and the formation of accommodation space, playing a key role in hydrocarbon source rock maturation, reservoir development, and trap formation. Recent advancements in natural gas exploration within the Ediacaran strata of the Sichuan Basin have revealed the substantial hydrocarbon resource potential of the Neoproterozoic sequences in the Upper Yangtze Craton. These exploration successes are intimately associated with the development of deep-seated extensional rift systems in the Yangtze Craton, which are interpreted as the result of rapid lithospheric extension following cratonization during the early Neoproterozoic. Despite these breakthroughs, a comprehensive understanding of the structural geometry, kinematic evolution, and petroleum systems of these rift systems remains limited, highlighting the need for further systematic investigation. This study integrates two-dimensional and three-dimensional seismic data with magnetotelluric data, deep borehole records, and field outcrop observations to construct, for the first time, a three-dimensional structural model of the Neoproterozoic rift systems in southwestern Sichuan Basin. The results reveal two distinct rifting phases during the Early to Middle Neoproterozoic, with rift dimensions ranging from 3-8 km in width and 7-23 km in length. The rift systems and associated fault networks predominantly display NE and NNE trends, with faults generally dipping northwestward. These faults governed the development of half-grabens during both rift phases, each accompanied by sedimentary deposits reaching thicknesses of 2–3 km. The stratigraphic sequences within the rifts exhibit strong correlations with the Neoproterozoic strata exposed along the western margin of the Yangtze Craton. Chronological evidence indicates that the first rift phase (800–720 Ma) was characterized by independently developed sub-rift basins. The second rift phase (720–635 Ma) inherited and expanded upon the earlier rifting, culminating in the development of a unified, large-scale half-graben that overlies the

sub-rifts of the first phase. During the late syn-rift stage, significant compressional uplift along the western Yangtze Craton margin induced structural inversion of several pre-existing rift normal faults in southwestern Sichuan and the formation of pre-Ediacaran reverse faults. This compressional event eroded over 3 km of rift-related sequences. The Neoproterozoic rifting and subsequent compressional deformation along the western Yangtze Craton margin are closely tied to subduction and rollback dynamics of the Pan-Oceanic plate. This study emphasizes the excellent conditions for hydrocarbon source rock and reservoir formation in the Neoproterozoic of southwestern Sichuan, highlighting its vast potential as a target for future hydrocarbon exploration.