Study on the evolution of paleo-uplift in southeast Sichuan

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Abstract. The deepening understanding of the geological structure of large paleo-uplift in the basin is often accompanied by important oil and gas exploration discoveries. The abundant oil and gas exploration results in the early stage show that the luzhou paleo-uplift is one of the important petroleum accumulation structural units in the sichuan basin. At the same time, the formation and evolution of luzhou ancient uplift were also affected by a variety of geological factors. It is a joint response of the internal deformation of the Yangtze plate and the orogenic movement of the peripheral block in the indosinian period, and a natural place to study the basin-mountain coupling relationship and the basin superposition transformation process. By means of a large number of seismic reflection profile and drilling data, combined with field exploration and other data, the temporal and spatial distribution characteristics of luzhou ancient uplift are described in detail. Combined with the tectonic background of the study area, the formation of luzhou ancient uplift was further analyzed, and the genetic mechanism model of luzhou ancient uplift was proposed. Through analysis, it is concluded that the indosinian luzhou ancient uplift developed in the southeast of sichuan basin, and its long axial strike is from northeast to southwest, which is a typical compressive and superimposed ancient uplift.

Keywords: Southeast sichuan, ancient uplift, structure, Triassic, evolution, Yangtze plate

1. The Introduction
Petroleum exploration of Marine carbonate rocks in sichuan basin of China has been carried out for more than ten years. In particular, in the past ten years, large and extra-large gas fields with 100 billion cubic meters have been discovered, such as puguang gas field, longgang gas field, yuanba gas field and anyue gas field. This indicates that sichuan basin is rich in natural gas resources and has certain mining value. It also reflects that with the progress of exploration theory and drilling technology, an innovative breakthrough has been made in the traditional anticline oil and gas exploration theory. The exploration of the sichuan basin has entered a new stage in the search for the complex gas fields combining reef and shoal facies, karst facies carbonate porosity reservoir and ancient uplift. In different geological periods, the sichuan basin has formed paleo-uplift with different scales and different oil-gas controlling actions.
The Paleozoic gas fields of its Marine facies are mainly distributed in luzhou, kaijiang, leshan and longnu temple, etc., so the paleo-uplift is also an important oil-gas accumulation structural unit in sichuan basin.

This article main research area is located in the southeast of sichuan basin, as early as 1953 in the region for oil and gas exploration, and discover the yongchuan huanggua mountain field, with the deepening of exploration and discovered the region there are ancient uplift of indo-chinese epoch, its high uplift area in Yang Gao Si and nine KuiShan tectonic zone, the residual jia three sections of the jialing river group stratum, uplift rate is 800 m high, wide scope of denudation, up to $2 \times 10^4$ km$^2$.

2. Stratigraphic profile of southeast sichuan
The sichuan basin belongs to the yangzi stratigraphic area. Except the western margin where several basement complexes are exposed, most of the rest areas are covered by sedimentary caprocks. The study area belongs to the southeast of sichuan basin, and its main tectonic - sedimentary evolution process is closely related to sichuan basin. The stratigraphic division of the study area belongs to the south China stratigraphic region, and the upper Yangtze stratigraphic division of the yangzi stratigraphic region, including the emei, chongqing and xuyong stratigraphic communities. The strata in the study area are well developed. The main metamorphic rocks in the banxi group of sinian are sedimentary basement, and most strata from sinian to quaternary have been deposited except the large area of missing devonian and tertiary. The upper part of the middle Permian maokou formation, the upper part of the middle Triassic jialingjiang formation and the leikoupo formation are missing locally.

ChuanDongNa region formerly Cambrian system are exposed to the quaternary system, basin out outdoor layer is given priority to with Mesozoic group, every file type fold zone of the yanchang formation mainly for outdoor layer, from the core to wing gradually upward from the next Jura Jura transition, fold syncline area outdoor layer and update than anticline belt, mainly, upper Jurassic in, in addition, as part of the anticline area has been found in the Paleozoic strata HuaYingShan anticline belt. From the southeastern part of sichuan to the middle part of sichuan, the outcrop strata are gradually new, and the upper Jurassic is mainly exposed in anyue, suining and dazu areas. Research area in the south of the rival - chishui mountain - the qijiang count area that feature exposed big cretaceous and direction of east, south elevation increased, to suck, chongqing southeast superimposed fold belt, outdoor floor also quickly by the new age, wenxin - from - the nanchuan a line out the outdoor layer of yanchang formation, anticline belt out outdoor layer is given priority to with early Paleozoic strata, including the Cambrian, ordovician and silurian system, has been found in Precambrian strata, parts of fracture in the area is very development, multiphase tectonic superimposition, formed the complex strata outcropped area, are shown in figure 1 below.

![Fig. 1 Study area design interpretation of seismic profile skeleton](image-url)
3. Basic geological structure of southeast Sichuan
Sichuan basin, located in the western margin of the upper Yangtze block, is a tectonic basin formed since the Cenozoic era. The dividing line between basin and mountain is obvious, and the main tectonic and geomorphic units from west to east are west Sichuan Plain, middle Sichuan Hill and east Sichuan parallel ridge and valley belt. The study area belongs to the southeastern part of Sichuan basin. The surface is characterized by the development of high and steep anticline belts and low and gentle fold belts. The west to the central Sichuan area is connected with the Weiyan anticline belt, and the west to the west is the western Sichuan depression belt. The basic geological and geomorphic structural units of the study area are analyzed by means of horizon tracing and tectonic interpretation of regional seismic reflection large section and the application of DEM digital elevation map.

4. A brief history of tectonic - sedimentary evolution in southeastern Sichuan
In the southeast of Sichuan basin, there is a complex basin-mountain transition process, and the sedimentary cover layers have undergone multiple tectonic cycles superposition, such as Yangtze, Tongwan, Caledonian, Dongwu, Indosinian, Yanshan and Himalayan, forming a relatively complex structural pattern. The Yangtze cycle includes the Jinning movement and the Chengjiang movement, which respectively formed the crystalline basement of the Yangtze platform and the early sedimentary cover. Then the Tongwan movement led to the wide unconformity between Sinian and Cambrian. To Caledonian - Dongwu stage, the South China block by the original Tethys ocean to reduce the influence of the northern margin of Gondwana continent dive, a wide range of intracontinental orogeny, the study area from stable carbonate platform gradually into squeezing properties of the clastic basins, and ultimately uplift for land, to suffer long time weathering denudation, before until the Permian deposition in the study area to happen again transgression to accept a wide range of sedimentation; Middle and late Triassic started by Indosinian movement phase of continental collision, the Sichuan basin peripheral from predominantly passive continental margin environment gradually into the evolution of the foreland basin stage, gradually from extensional environment of late Permian to squeeze the environment, ChuanDongNa region entered by Luzhou paleo-high uplift and denudation stage. During the Yanshan to Himalayan periods, the compressive stress of the peripheral block further strengthened, the study area underwent a wide range of fold uplift, the continental sedimentary range gradually narrowed and eventually completely uplifted to the land, suffered from erosion and formed the present tectonic pattern.

5. Geological structure of Luzhou ancient uplift
Through the Triassic stratigraphic correlation, it can be found that the Triassic strata in the upper Yangtze and its surrounding areas are generally missing, among which the Triassic strata in Chongqing district in the upper Yangtze stratigraphic division are most seriously missing. Especially in Yanggaosi, Jiukuishan and other areas of Luzhou, the strata from the late Orenkian of early Triassic to the late Karni of late Triassic have been lost, which has been denuded to the middle of the third member of Jialingjiang formation, as well as the lower strata of Leikoupo formation and Xujiahe formation.

5.1. Drilling formation response
The drilling formation data can most directly reveal the lithologic assemblage characteristics and formation absence in this area. By analyzing the well-connected formation profile, the formation absence thickness and formation pinch-out characteristics during the development of the palaeo-uplift can be intuitively reflected, and the temporal and spatial distribution range of the palaeo-uplift can be preliminarily determined.

Figure 2 Tectonic and sedimentary evolution of the middle Triassic to late Triassic in the western margin of the upper Yangtze, flattening the Triassic Xujiahe group at the top of the river, can be found: Sue, from in the western Sichuan depression area code 1 well, a upper uplift siltstones spatial 17 Wells, stone 28 Wells, high stone to ChuanDongNa of slope zone of deep well, screw 1 well, and then to the southeast margin of Sichuan basin close 1 well, the qijiang count until is Ann area in guizhou, general
trias thickness has the characteristics of thinning gradually from west to east. Among them, feixianguan formation has the characteristics of west, east and thick. The strata of the jialingjiang formation in luoguan 1 and guan1 Wells in the southeast of sichuan have suffered from denudation and are in unconformable contact with the overlying xujiahe formation. The lei koupo formation has a tendency of thin in the middle and thick at both ends, and the fourth, third and second sections of lei koupo formation are gradually missing from the east and west sides to the middle. The xujiahe formation of the upper Triassic shows a trend of gradual thinning from west to east, and has an unconformity contact with the underlying leikoupo formation and jialingjiang formation.

Fig. 2 Tectonic and sedimentary evolution of the middle Triassic to late Triassic in the western margin of the upper Yangtze

5.2. Evidence on seismic profiles
Seismic reflection profile can directly reflect the characteristics of underground geological structure. Thanks to a large number of drilling and logging data and seismic reflection data in the research area, through the production of synthetic seismic records, a large number of two-dimensional seismic reflection data in the research area have been tracked and identified.

Seismic reflection profile B is located in the northwestern margin of the ancient uplift, and its stratigraphic distribution is relatively gentle. It is found that the stratum upward from the middle Permian is present as a nw inclined monoclinal structure, and the stratum deformation is weak. In the Triassic strata, the thickness variation of feixianguan formation is stable and easy to recognize. In particular, the upper part of the jialingjiang formation has a more obvious change in stratum thickness, which is in unconformity with the overlying xujiahe formation in the southeast. As a whole, the leikoupo formation is wedge-shaped, gradually thinning from northwest to southeast until pinching out, and has unconformity contact with the overlying xujiahe formation. The thickness of xujiahe formation also decreases from northwest to southeast. In Jurassic, the stratum thickness is stable again.

After the local amplification of seismic section B, the contact relationship between each group can be clearly observed. In the lower gentle slope of the northwest luzhou ancient uplift, the top reflection axis of the lower Triassic jialingjiang formation is terminated by the bottom reflection axis of the leikoupo formation, which reflects the feature of the top of the jialingjiang formation being truncated. The internal reflection axis of the middle Triassic leikoupo formation shows the characteristics of
gradually overlying and thinning from west to east at the bottom until tapering out, and gradually cutting and truncation at the top from west to east. At the bottom of the xujiahe formation of the upper Triassic, the overlap to the top of the leikoupo formation can be seen.

5.3. Distribution range of ancient uplift

Based on the comprehensive use of drilling, outcrop profile and 2d and 3d seismic profile data, the morphology and distribution range of the ancient uplift were determined by searching the overlying line and cusp point of the leikoupo formation at the edge of the ancient uplift. The stratigraphic denudation was most serious in the core area of the paleo-uplift before the late Triassic, in which the leikoupo formation had been completely denuded, the missing area of the first lei section in the sichuan basin was 1.46 104km2 before the late Triassic deposition, and the top of the jialingjiang formation was also severely denuded in some areas. The stratigraphic distribution range of the remaining lei section is consistent with the luzhou ancient uplift, mainly around the core of the luzhou ancient uplift, and presents a pattern of gentle uplift in the southeast wing and steep uplift in the northwest wing. The exposed area in the sichuan basin was about 3.98 104km2 before the deposition of the late Triassic. The residual strata of lei 2nd member in sichuan basin have a smaller distribution range. Before the late Triassic deposition, the residual strata mainly appeared in the eastern part of the basin and were trending from northeast to southwest. Before the late Triassic deposition, the outcropping area in sichuan basin was about 6.99 104km2. On the basis of the stratigraphic distribution of the second lei member, the distribution range of the third lei member is shrinking towards the west wing of the luzhou ancient uplift. Before the late Triassic, it was mainly exposed to the west of the first line of zigong, hechuan and dazhou, and in the dian-jiang-wanxian depression. Before the late Triassic, the outcropping area in the sichuan basin was about 3.22 104km2. The fourth lei member has the most limited distribution range. The fourth lei member is mainly distributed in the west of leshan, guang’an and qu county in the western part of the basin. The thickness gradually increases from east to west.

6. Conclusion

In this paper, structural geology, sedimentology, petrology, seismic stratigraphy and petroleum geology and so on the basis of the theory and method, through the comprehensive utilization of drilling core, well logging, the field profile observation and seismic profile interpretation and so on a variety of technical means, in basic geological structure of the ancient uplift ChuanDongNa region, space-time distribution and the causes of formation and evolution mechanism and so on has carried on the exploration, and on this basis, combining with the process of oil and gas exploration in the study area, discussed the palaeohigh evolution of oil and gas formation. The comprehensive interpretation results of drilling, outcropping and seismic reflection profile reveal that the indosinian luzhou ancient uplift developed in the southeast of sichuan, and the core area of the luzhou ancient uplift before the late Triassic deposition is 1.46 104km2 according to the present tectonic pattern. The core area is located in luzhou yanggaosi-gufoshan area, extending to the north dazu - neijiang line, to the west can reach yibin - zigong area, to the east to chongqing, qijiang area, to the south can reach guizhou chishui area.

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