

乌蒙山区典型富水型背斜泉群成因机理研究

——以绥江县新滩镇银厂村幸福泉为例

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摘要:乌蒙山区划跨云南、贵州、四川三省,是国家新一轮扶贫开发攻坚战主战场之一,五角堡背斜位于乌蒙山区中部,分布于绥江县五角堡至屏山县楼东一带,背斜周边共出露天然泉点 45 个,幸福泉位于五角堡背斜北西翼,距离核部 2km,枯水季流量 141L/s,丰水季流量 822L/s,为新滩镇供水水源地。根据前人调查,此泉的成因机理研究主要有两种截然不同的理论,一种为“上升泉理论”,一种为“下降泉理论”,针对这两种理论,以现场调查、示踪试验及地球物理勘探为依据,对幸福泉成因机理进行深入分析并提出自己的观点,认为幸福泉为岩溶裂隙上升泉,为此后同类富水性背斜泉群的研究及该地区地下水资源的合理开发利用提供科学依据。

关键词:乌蒙山区;富水性背斜;幸福泉;成因机理

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泉是地下水的天然露头。当雨、雪水、冰雹渗入地下后就形成了地下水。地下水在地下沿缝隙、孔窍流动或蓄积^[1]。当径流前行受阻且遇见一个通向地面的缝隙时,就会溢出,或者说当潜水面被地面切断时,地下水即可溢出地表^[2]。这种渗出的水如果沿着固定的出口,源源不绝地流出,就被人们称为“泉”。在自然界中,形成泉的条件多种多样,因此泉的种类和应用价值也非常多^[3]。它决定于许多外界因子,其中最重要的是地质构造、地貌和水文地质条件等^[4-7]。

乌蒙山片区即乌蒙山集中连片特殊困难地区,是贫困人口分布广、少数民族彝族、苗族聚集多的连片特困地区,是国家新一轮扶贫开发攻坚战主战场。五角堡背斜分布于绥江县五角堡至屏山县楼东一带,周边泉点呈环带状分布,一共出露天然泉点 45 个,其中流量最大的为绥江县新滩镇银厂村幸福泉,幸福泉泉口海拔高程约 854m,位于北纬 28°33'7.1",东经 104°06'58.9"。该泉以泉群的形式呈辐射状成股涌出,枯水季流量 141L/s,丰水季 822L/s,现为新滩镇供水水源地。本文在现场水文地质条件调查的基础上,以示踪试验及地球物理勘探为依据,提出了幸福泉的成因机理,认为幸

福泉所处地形为一干沟底部,由于地形切割,表层的峨眉山玄武岩被剥蚀掉,导致下部阳新灰岩出露,而出露的阳新灰岩正好为岩溶管道中地下水径流通道,地下水在此处以承压状态排泄。

1 水文地质条件

幸福泉位于金沙江右侧,新滩镇东南方向,距绥江县城约 24km,离新滩镇约 10km,泉域面积约 11.47km²。幸福泉为域内主要河流清水溪的源头,泉口可明显观察到泉水从灰岩裂隙通道内涌出,距离泉口 10m 处修建有引水堰,下游为新滩溪。泉域内沟谷切割强烈,高差悬殊,主要以新滩溪及其域内支流清水溪、域外支流铁厂沟和石岗坪沟为主,新滩溪、清水溪两侧山势陡峻,沟谷纵横,形成树枝状水系。

泉域范围内出露的地层以二叠系、三叠系为主,包括二叠系下统阳新灰岩、上统峨眉山玄武岩、龙潭组,三叠系下统飞仙关组、嘉陵江组、中统雷口坡组以及上统须家河组,第四系全新统的松散堆积物则分布于河流沟谷沿岸。

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泉域内的主要构造为五角堡背斜(见图1),该背斜主体呈北东向展布,与金沙江呈 25° 左右角相交于楼东一带。背斜核部出露二叠系下统阳新灰岩约 11.47km^2 ,并由二叠系上统龙潭组和峨眉山玄武岩构成圈闭。背斜两翼主要为三叠系雷口坡组、嘉陵江组及飞仙关组地层。背斜各含水岩组呈环带状展布,利于地下水的赋存。据调查资料分析表明,背斜核部裂隙、岩溶发育,地下水丰富,为一天然“大水库”。总的来看,该背斜轴部开阔,两翼产状较平缓,为短轴背斜型富水构造。

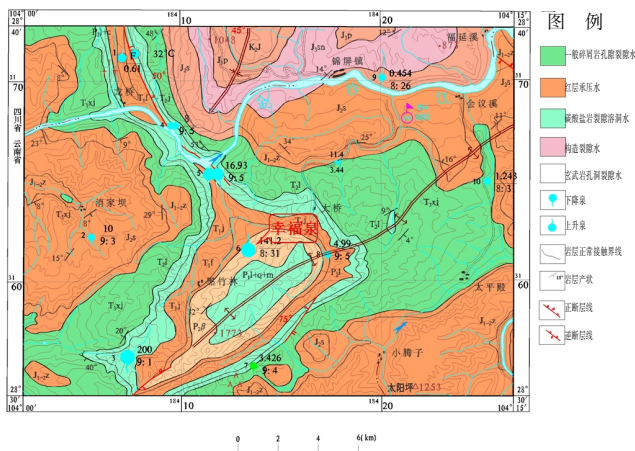


图1 五角堡背斜幸福泉泉域周边水文地质简图
Fig.1 The hydrogeology of the Wujiaobao anticline around the Xingfu spring area

2 历史研究理论分析

1980年开展的筠连幅1:20万区域水文地质普查。针对五角堡富水地质构造中的岩溶大泉(今幸福泉),普查报告认为^[9]：“五角堡背斜由茅口组石灰岩构成核部,外侧由自流井组泥岩完全圈闭,期间各含水岩组呈环带状展布,茅口组在完全封闭的情况下,岩溶水从标高790m以上以承压状态集中在北翼玄武岩底部排泄。”其认为幸福泉为上升泉,补给来源主要为五角堡背斜自身。

2007年开展的云南省绥江县新城供水工程水源论证,将“幸福泉”作为绥江县新滩镇供水水源地,论证报告认为^[9]：“幸福泉出露于五角堡背斜核部阳新灰岩地层中,阳新灰岩地层的倾向是南高北低,这样,灰岩中地下水的侧向径流基本上都汇集到幸福泉。”其认为幸福泉为下降泉,根据泉域流量对比,幸福泉补给区不仅仅为五角堡背斜,还包含外来水流量(见图2)。

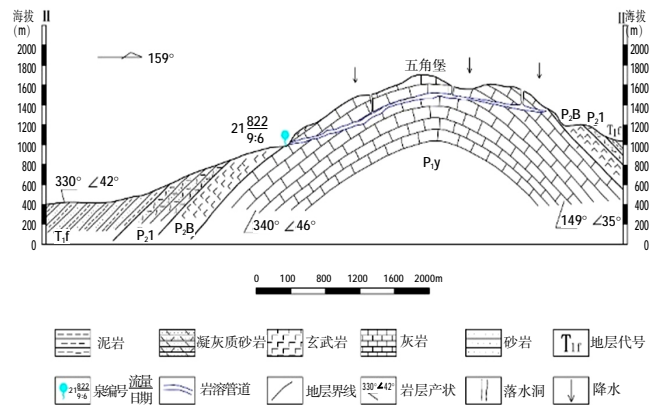


图2 绥江县新城供水工程水源论证幸福泉成因机理图^[9]
Fig.2 The Xingfu spring cause mechanism of water supply project demonstration in Sujiang County

3 示踪实验

3.1 实验原理

示踪探测的原理是在质量守恒定律的基础上,根据示踪剂在不同类型不同结构地下水流动场中的弥散规律识别和了解流动的面貌并计算各种流动场参数的技术手段。本次研究区范围大致为五角堡背斜的核部,以背斜核部落水洞、北西翼大泉幸福泉为重点研究对象

3.2 示踪剂选择与准备

由于研究区地下水具有居民饮水供给、灌溉等功能,所选示踪剂不能够对地下水水质产生影响,此外,还考虑到研究区地下水环境背景值、岩石的吸附作用等因素,故在本次连通示踪试验中,试验选用荧光素(分子式: $\text{C}_{20}\text{H}_{12}\text{O}_5$)作为探测的示踪剂。

3.3 示踪剂投放及监测点布置

根据试验目的及任务要求,由于五角堡背斜核部海拔高程为1100~1783m,高出幸福泉(海拔高程:854m)246~929m,处于幸福泉的上游补给区,且五角堡背斜核部广泛分布着二叠系下统阳新灰岩,约 11.47km^2 ,背斜核部裂隙、岩溶发育,地下水丰富。因其具备连通试验的条件,此次试验选择五角堡背斜核部石料厂内的落水洞作为示踪剂的投放点。

试验于2016年11月20日上午11点29分在石料厂落水洞投放示踪剂,以示踪荧光仪检测,投放量为1kg,在10min内将试剂充分溶解于水并投入落水洞中,同时开始监测。监测点布置在幸福泉泉口,确定的投放点和监测点如表1和图3所示。

表1 试验点布置情况一览表
Table1 The location of the test points

试验点	名称	位置	海拔高度/m
投放点	石料厂落水洞	五角堡背斜核部	1 250
监测点	幸福泉	五角堡背斜核部北西翼	854

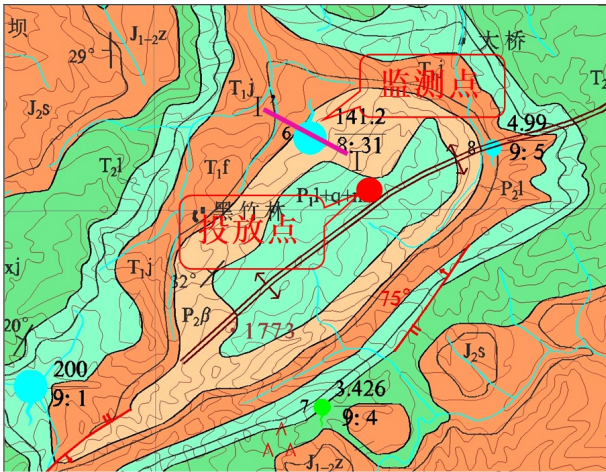


图3 示踪剂投放及物探剖面线 I-I' 平面位置示意图
Fig.3 The plane position of tracer dropping and geophysical exploration profile I-I'

3.4 试验成果分析

本次连通示踪试验在五角堡背斜北西翼银厂村幸福泉接收到了示踪剂,试验成果曲线图见图 4。

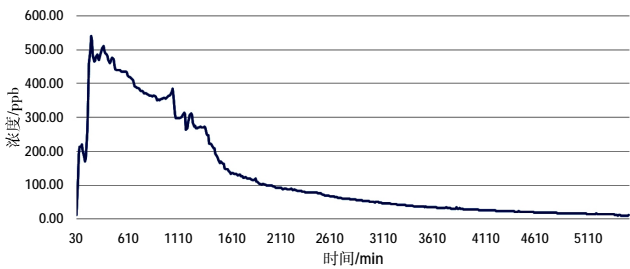


图4 幸福泉示踪实验成果曲线图
Fig.4 The results of the Xingfu spring tracer experiment

从图 4 中可以看出,荧光素示踪曲线在示踪剂投放后 2h 时浓度检测出现异常,至 92h 时恢复正常,异常波段持续 90h,峰值出现时间为投放后 5h,峰值浓度 540ppb。

在五角堡补水区-排泄区幸福泉进行的示踪试验表明,地下水从五角堡背斜核部落水洞径流至幸福泉泉口仅历时 2h,这一方面表明地下水流速极高,另一方面表明五角堡的洼地、落水洞与幸福泉之间存在岩溶管道,才能使地下水在如此短时间内径流如此长距

离(1.5km)。在岩溶管道内岩溶含水介质发育不均匀,这说明流速的微小变化容易发展、增强,形成紊乱、不规则的紊流流场。五角堡一带的补给区接受大气降雨补给后,沿地下岩溶管道较为快速地抵达幸福泉排泄区。

4 地球物理勘探

本次调查沿幸福泉的纵剖面布置了 600m 地球物理勘探高密度视电阻率剖面线(见图 3),获得反演成果如图 5 所示。

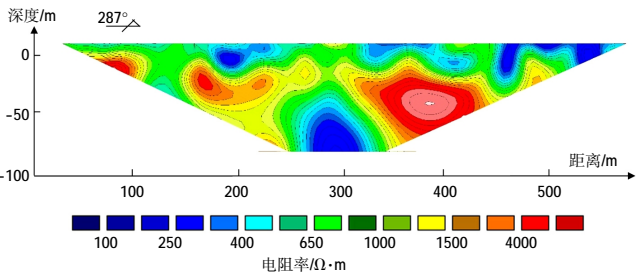


图5 幸福泉高密度视电阻率物探反演等值线图
Fig.5 The geophysical inversion contour of high-density apparent resistivity of the Xingfu spring

工作区主要出露为灰岩,一般情况下其电阻率属于高阻。但由于岩溶发育且大量充水,其高密度反演等值线上其电阻率值最低时仅有几十欧姆·米,远小于灰岩阻率值。在剖面上,测点 250~350m 点之间,深度自 40~100m 处,存在一低阻异常带,异常值远小于周边围岩视电阻率值,深部未封闭,物探推断主要为岩溶管道或者导水断层发育,含水情况较好。

5 结论

经过现场水文地质调查分析、示踪实验分析以及对前人研究理论对比分析,认为幸福泉为岩溶裂隙上升泉,其成因机理的分析为:五角堡背斜核部裂隙、岩溶发育,补给以大气降雨为主,在五角堡地区发育较多的落水洞,峰丛-干沟-落水洞的组合使降水很快汇集渗入地下,地表沟谷成为干沟,形成了五角堡地区降水灌入式补给的特征。入渗的地下水储存于下部灰岩中,形成含水丰富的天然“水库”,地下水资源丰富。核部二叠系阳新灰岩地层由于受到环带状峨眉山玄武岩的封闭,与顶部潜水面形成了较高的水头差,地下水在玄武岩底部以承压状态埋藏。幸福泉所处地形为一干沟底部,由于地形切割作用,部分表层的峨眉

山玄武岩被剥蚀掉,导致下部阳新灰岩出露,而出露的阳新灰岩正好为岩溶管道中地下水径流通道,地下水在此处以承压状态排泄,支撑依据如下:

(1)现场调查中,泉点附近地层为阳新灰岩,周边均为峨眉山玄武岩地层,可明显看见泉水以大腿状向上涌出;

(2)五角堡背斜核部阳新灰岩含水层出露位置较周围隔水层高,且面积大,为理想的补给区,其两翼环带状峨眉山玄武岩封闭条件好,为地下水的承压性创造了良好的条件。

(3)示踪实验数据显示,地下水以较快速度从五角堡背斜核部沿岩溶管道径流至幸福泉,说明两处的水力联系密切,为核部岩溶落水洞及岩溶管道直接补给,其补给通道连通性好,存在的水头差可使幸福泉处于承压状态。

(4)物探成果资料显示,幸福泉深度自 40~100 m 处,存在一低阻异常带,推测为岩溶管道或者导水断层发育,表明幸福泉径流路径较深,最后经岩溶管道或导水断层以承压状态垂直向上出露。

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Genetic Mechanism of Typical Water-rich Anticline Spring Group in Wumeng Mountain Area: A Case of Xingfu Spring in Yinchang Village, Xintan Town, Suijiang County

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Abstract: Wumeng Mountain stretch across Yunnan, Guizhou and Sichuan provinces. It is one of the battlegrounds for the new round of poverty alleviation in China. The Wujiaobao anticline is located in the middle of Wumeng Mountain, and distributed in the area from the Wujiaobao of Suijiang County to Loudong of Pingshan County. There are 45 natural springs exposed in the periphery of the anticline. The Xingfu Spring is the water supply source of Xintan town that 2km away from the core, which is located in the northwestern wing of the anticline of Wujiaobao, and the seasonal flow is 141L/s and 822L/s in the low water season and in the abundant water season respectively. According to the previous investigations, there are mainly two different theories on the genesis mechanism of the spring, one is the theory of "rising springs" and the other is the theory of "falling springs". According to the above theories, this paper made an in-depth analysis of the genesis mechanism of the Xingfu Spring and put forward its own point of view based on field investigation, tracer test and geophysical prospecting. It will provide a scientific basis for the research on the same type of water-bearing anticline springs and the rational exploitation and utilization of groundwater resources in the area.

Key words: Wumeng Mountain area; water-rich anticlines; Xingfu Spring; genetic mechanism

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Analysis of Temporal-spatial Distribution Characteristics of Water Quality Monitoring Stations in Poyang Lake

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Abstract: How to set up water environment monitoring sites will have a direct effect on evaluating the water environment. The key point of accessing the Poyang Lake water quality status and evolution trend is to establish a scientific and reasonable monitoring system in terms of time, space and frequency. Based on the analysis of sites distribution and monitoring data from the relevant agencies, the water environment monitoring sites in the Poyang Lake should be set up as follows: (1) There should be 35 sites and 29 sections for environment monitoring in the Poyang Lake every year; (2) Water sampling should be taken at least once a month without human production activities, such as sand mining. The time of sampling should be put on the late of month, and there should be no raining 5d before sampling and the transparency of sampling should beyond 30cm; (3) Due to high spatial heterogeneity in the Poyang Lake, and the water sampling only reflects water quality monitoring results in its area, it needs to take sampling from different areas; (4) Sampling should be conducted in the reverse water flow direction to ensure its diversity; (5) Water environment monitoring should be carried out with hydrologic monitoring simultaneously, and monitoring indicators should include at least nutrient and physical parameters.

Key words: Poyang Lake; water environment; hydrology; temporal-spatial sites distribution