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# 测氦技术在泉州清源山地下水源勘查中地应用

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**摘 要:** 测氦是一种有效的放射性地球物理探测方法。由于含水裂隙基岩与其周边岩体的结构存在差异, 氦气的浓度异常可间接反映出地质体裂隙系统的情况, 并可分析其开启度、连通性, 以及破碎程度。应用测氦技术对地下水资源进行勘探, 对含水裂隙基岩的结构特征进行研究, 能达到节约投资, 缩短勘探时间的目的。并可与地质资料分析相互验证, 为地下水勘察应用提供依据。这里将测氦技术应用于泉州市清源山地下水资源勘探工作中, 旨在寻找基岩山区地下水富集带。测氦结果显示, 在清源山一带明显存在二条北西西向和北西向断裂, 结合地质资料认为: F1断裂带和 F2断裂带是地下水赋存的理想位置, 而且这二条断裂延伸 2.5 km~3.0 km, 汇水面积大于 13 km<sup>2</sup>, 大气降水的补给能力 5 770 m<sup>3</sup>/d 每年的补给量可达 211×10<sup>4</sup> m<sup>3</sup>。

**关键词:** 测氦技术; 氦异常; 地下水  
**中图分类号:** P 631.6<sup>+</sup> 32     **文献标识码:** A

## 0 前言

随着社会经济的迅猛发展, 地下水的开发利用在国民经济建设中的作用日益增强, 尤其是在干旱贫水地区, 找寻基岩裂隙水、岩溶水更为迫切。随着地下水资源勘探难度的增大, 迫切需要有更先进、更有效的方法技术配合地下水开采工作。在上世纪七十年代中, 氦气测量技术开始用于水文地质工作。

氦 (Rn) 是一种放射性的惰性气体, 易溶于水, 属于天然铀放射系列<sup>[1]</sup>, 是铀、镭衰变的子体。氦气测量技术 (简称测氦技术), 是一种放射性勘探地球物理技术及方法<sup>[2]</sup>, 在找矿、发现断裂构造、地震预报、环境监测、油气勘探、岩溶塌陷探测, 以及滑坡研究等领域, 均得到了应用<sup>[3~5]</sup>。但与铀矿资源的勘探所不同的是, 在水文地质勘探时, 对氦

气测量技术要求是高精度、高灵敏度、多参数的测量技术, 以便于发现并处理地质勘探问题中常是微弱的放射性氦气异常。因此, 氦气测量技术在解决水文地质问题等领域中的应用是值得研究的课题<sup>[6]</sup>。

近年来, 放射性方法在水文地质和工程地质等问题上的应用, 已得到了国内、外学者的重视。目前, 我国已有关于测氦技术找寻基岩地下水成功应用的报道<sup>[7]</sup>。此外, 对壤中氦气进行测量, 还可以有效地勘查隐伏断裂<sup>[8]</sup>、探测花岗岩地区基岩裂隙水<sup>[9]</sup>。因此, 作者在本文应用壤中氦气测量技术, 对泉州市清源山地区隐伏断裂和基岩裂隙水进行了勘查研究。

## 1 测氦技术的基本原理

富含 Th U 等放射性元素的地质体, 衰变释放

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出来的氦气因自身的机制,有着很强的向上运移能力。而活动断层、构造活动带、岩溶带,以及滑坡地段等现代地动带形成的断裂和裂隙,可成为地下深处的氦气向上运移的良好通道。同时,由于氦气是惰性气体,在迁移过程中不与其它物质发生化学反应。因此在地表土壤中,高浓度的氦气和宽广平缓的氦异常,可较为准确地反映地质体的裂隙系统的开启度、连通性及破碎程度,从而指导寻找基岩裂隙水。

地质工作中的测氦方法,大多以氦子体为测量对象。氦子体是氦衰变的产物,包括  $Po$   $Bi$   $Ph$   $Tl$  等,其中  $Po$  的同位素都是  $\alpha$  辐射体,其它的多为  $\beta$  和  $\gamma$  辐射体。这些子体大多是短寿命的固态放射性核素,它们会在有氦气经过的物体上沉淀下来<sup>[10]</sup>,一般多富集于地表土壤之中。

作者在本次研究中,所选用的是成都理工大学自主研制的  $KJD-2000R$  型测氦仪。该仪器是一种新型的连续测氦仪器,属于标准测氦方法之一。它可利用静电收集氦衰变子体进行累积测量,具有灵敏度高,操作方便的优势,可用于室内测氦,壤中测氦,水溶液测氦等领域。本次测量为壤中测氦。仪器的检测对象为  $^{222}Rn$   $^{220}Rn$  采用半导体  $\alpha$  粒子探测器;具有实时  $\alpha$  能谱显示和 512 道分析器;本底小于 5CPH;灵敏度为  $3\text{ Bq/m}^3$ ;测量范围为  $3\text{ Bq/m}^3 \sim 40\,000\text{ Bq/m}^3$ ;测量不确定度为  $<10\%$  ( $K=2$ );气泵的流量为  $1\text{ L/min}$ ;测量时间为  $5\text{ min}$ ;可自动保存测量 1 000 条谱线。

2 应用研究

本次测氦技术在地下水资源勘探中的应用研究区,选在福建省泉州市清源山。由于泉州市主要供水来源来自地表水,所以地下水开发利用程度不高,而且缺乏充足的备用水源。为了改变泉州市饮用水单一供水状况,应对突发性的水源污染事件,本项研究是为建立该市地下水应急水源地的前期基础研究,旨在寻找基岩山区基岩地下水富集带。

2.1 研究区概况

泉州市地处福建省东南部,南侧部份区域与漳州和厦门交界,部份区域临海,北临三明市,东与福州市、莆田市接壤,西与龙岩市相邻。泉州市区溪流众多,发源于泉州市境内的流域面积  $100\text{ km}^2$  以上的河流有三十五条,流域面积为  $7\,933\text{ km}^2$ 。其中,晋江水系十六条;九龙江水系五条;闽江水系九

条;单独入海五条,如图 1 所示。

2.2 地质、水文地质条件

(1)地层。工作区位于泉州市东北直距  $5\text{ km}$ ,地处清源山、群山、环山包围形成的小盆地。出露地层为第四系覆盖,侵入岩主要有加里东和燕山早期、燕山晚期所形成的侵入岩,它们的分布和展布严格受区内主要构造控制。

(2)构造。该工作区属于燕山早期侵入岩,多呈北东、次为北北东向,沿新华夏系主干断裂侵入,散布全区,构成壮观的岩带或呈“多”字形。其中,主要岩石有二长花岗岩、黑云母花岗岩、花岗闪长岩,以及石英闪长岩、斜长花岗岩、细粒花岗岩、闪长岩、辉石闪长岩等,呈全晶质花岗结构和块状构造。

(3)水文地质条件。研究区属新华夏系长乐~南澳断裂带。该区段由较密集的数条近平行压性断裂组成,呈北东向展布,带内岩石强烈片麻理化及混合岩化。构造脉状裂隙水主要赋存于西侧山脚地带,泉点多出露于北西向短小张断裂交汇部位,其中包括晋江古坡和深沪镇泉。由于过量开采或近期的新构造活动,泉流量减小,如图 2(见下页)所示。

2.3 测氦技术的应用

根据前述测氦技术的原理,在清源山附近选取三条剖面(见下页图 3),每条剖面布 101 个目标点,并对每个点进行测氦实验,获得其浓度。然后,找出氦浓度异常高的点。在这些点的位置上,下部



图 1 研究区地理位置图

Fig. 1 Location of study area

岩土体往往有较大空隙,可能预示着基岩断裂的存在,对寻找基岩裂隙水有很大的指导作用。

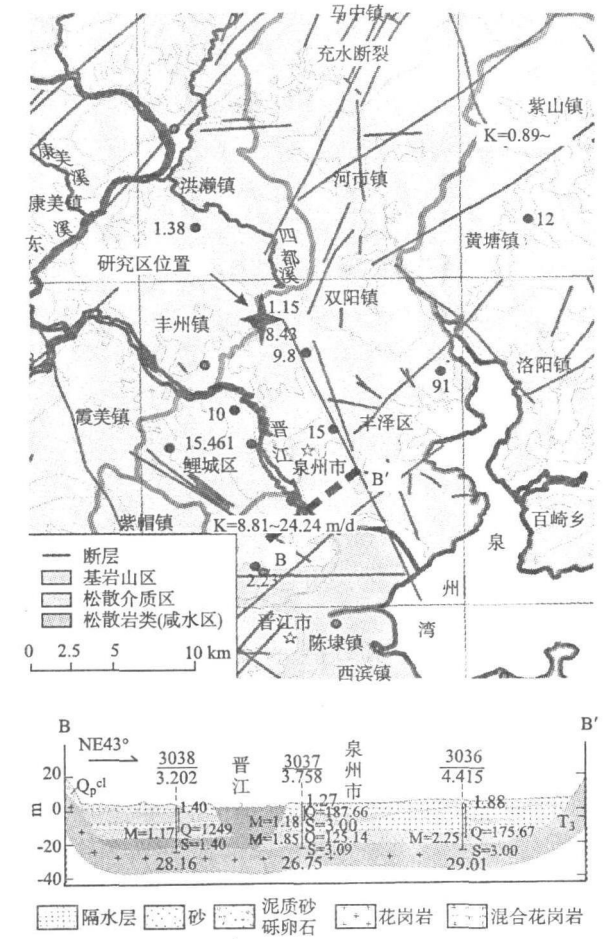


图 2 研究区水文地质及剖面图

Fig 2 Hydro-geological and profile map of study area



图 3 测氡点分布及异常点位置示意图

Fig 3 Distribution of radon detection and anomaly sites

野外测氡气含量持续二周,沿线氡气含量变化如图 4 所示。从图 4 中可以看出,在三条清源山剖面线中的 101 个测点中,氡浓度值超过  $40\,000\text{ Bq/m}^3$  的有 12 个,最高值为  $86\,205\text{ Bq/m}^3$ 。在经过 ARCGIS MAPGIS 等地理信息系统软件处理后发现,清源山脚下可能有二条较明显的断裂带(见图 3),一条为山前的北西西向断裂(F1),位置在 CM1-5~CM2-5~涌泉矿泉水厂 680/3 点,走向北西~南东,倾向南西。在该断裂带上测得氡气含量较高,宽度窄;另一条为山前的北西向断裂(F2),位于 CM3-2~CM1-3~CM2-3 走向北西~南东,倾向南西。在该断裂带上测得氡气含量相对较小,宽度较大。这两条断裂延伸  $2.5\text{ km} \sim 3.0\text{ km}$ 。此外,各线还存在多处规模较小的断裂。

结合地质资料作者认为: F1 断裂带是造山运动形成的; F2 断裂带是多次花岗岩侵入和后期构造运动形成的,是地下水赋存的理想位置。其中,靠西部的北西向断裂,比另一条靠山边的北西西断裂破碎宽度大。

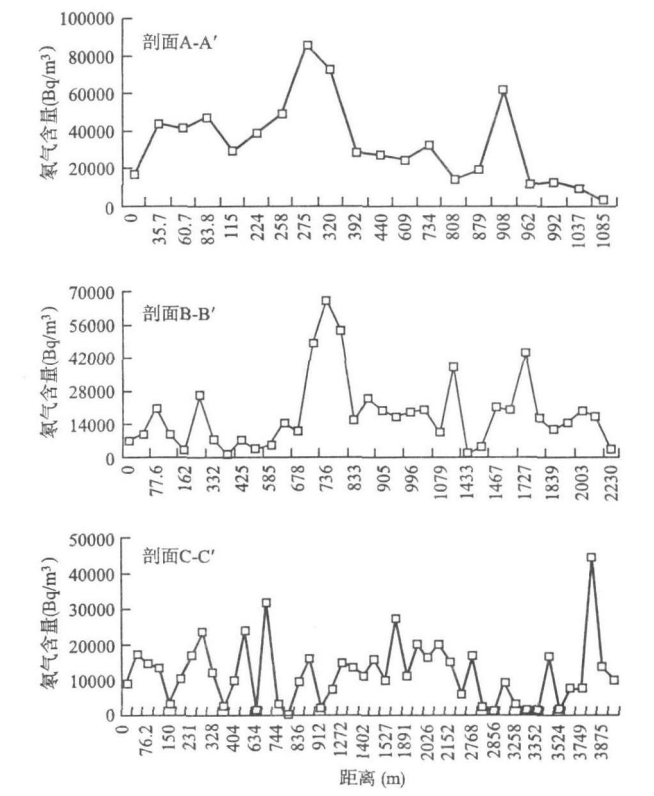


图 4 三条剖面氡气含量变化图

Fig 4 Variations of radon concentration on three profiles

## 2.4 地下水开发可行性分析

结合氡气测量和已有的钻探结果,为方便该断裂区矿泉水和温泉(深部地下水)的开发利用,有

必要进行地下水补给资源量的确定。

作者本次计算的是地下水补给资源量，F1断裂形成的补给区近似认为是清源山脉西南的一部份，属于裂隙水和浅层孔隙水；F2断裂形成的补给区为平原区，浅层为松散孔隙水，深层为裂隙水，其汇水面积仅延伸到后茂村，因为物探调查区域主要集中于燎原、肖厝、竹脚等区域，补给区面积可能更大，本次计算确定的补给区如图 5 所示。

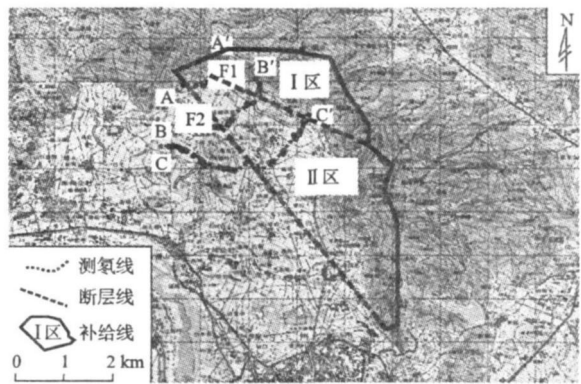


图 5 清源山二条断裂地下水补给区分  
Fig 5 Division of groundwater recharge areas in Qingyuan Mountain

根据测氦技术确定的断裂延伸范围可知，I区和 II区的补给面积分别为 3.5 km<sup>2</sup>和 9.6 km<sup>2</sup>。结合当地年降水量与降水入渗系数，构造水的补给量分别为 1 035.62 m<sup>3</sup>/d和 4 734.25 m<sup>3</sup>/d 合计为 5 769.87 m<sup>3</sup>/d 每年可提供 210.6 × 10<sup>4</sup> m<sup>3</sup> 地下水量。目前已有证实，F1断裂上的竹脚村矿泉水厂有一自流井，水量达 80 m<sup>3</sup>/d 并且常年不断，这说明本区水量尚有较大的开发潜力。

3 结论

- (1)测氦法是一种简便易行，勘探效果明显的定位地下水新源方法，应用测氦技术查明地下水源位置与地质分析判断吻合较好。
- (2)依据氦异常值进行地下水源的识别，判定在清源山一带明显存在二条北西西向和北西向断

裂。结合地质资料可以认为，这二条断裂是地下水赋存的理想位置，每年的大气降水补给量可达 211 × 10<sup>4</sup> m<sup>3</sup>；

(3)为了进一步探明地下水储量，氦气探测技术可与其它各种物探方法相结合，广泛应用于地下水源地的勘查中。

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sian ocean tectonic-metallogenic domain, the Daxing'anling mountain had typical Features of the multi-block mosaic hyperplasia orogeny. Had reformed and superimposed in a variety of metallogenic geological processes in the period of the mesozoic and cenozoic; it enjoyed very favorable ore-forming conditions for forming potential large-scale mine. Based on deeply study of the geologic tectonics and aeromagnetic features of multi-metal mineral exploration, the author comprehensively interpreted the aeromagnetic anomalies, trying to find the buried neuter-acidic rocks and hidden faults closely related with the mineralization. And then, with the geological theory and mineral exploring techniques, the author analyzed deeply the relationship between neuter-acidic rocks, hydrothermal tectonic activity and permian-strata mineralization closed related in the middle-south section of Daxing'anling mountain in order to delineate the high value of geological complexity and potential ore-forming region. All of the above aims to provide references for multi-metal mineral exploration in this area.

**Key words** middle-south section of Daxing'anling mountain; geological complexity; aeromagnetic anomalies; multi-metal mineral bed

## THE APPLICATION OF QUANTITATIVE ANALYSIS OF ROCK PHYSICS IN SEISMIC PROCESSING AND INTERPRETATION AT MOSUOWAN AREA OF ZHUNGAR BASIN

TANG Jian-hua, FAN Xu, WANG Xian, et al (Research Institute of Exploration and Development, Xinjiang Oilfield Company, Petrochina, Uluqi 830013, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2011, 33(1): 63

The lack of fundamental rock physics data is one of restrict factors to do rock physics research in exploration area. With similar sedimentary environment and structure trend of the deep buried Jurassic Sangonghe reservoir, the seismic rock physics research was firstly performed in the Mosuowan Permian development area nearby, which includes to use the log environmental calibration and scaling, calculating of the shearwave curve, selection of sensitive elastic parameters and quantitative analysis of the rock physics templates. Then the quantitative relationship is calibrated according to the new environment and applied in Moshier area where is a new exploration area. The quantitative analysis result gives the basis of quality control of the pre-stack gathers, pre-stack inversion and direct hydrocarbon detection.

**Key words** quantitative rock physics template; quality control of pre-stack gathers; AVO attributes

pre-stack inversion

## RESERVOIR DESCRIPTION OF THE ULTRA-DEEP CARBONIFEROUS RESERVOIR IN THE THIRD AREA OF TAHE OILFIELD

TIAN Jing, LOU Da-na, YU Teng-fei (Research Institute of Exploration and Development, Northwest Oilfield Branch, SINOPEC, Urumqi Xinjiang 830011, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2011, 33(1): 69

The carboniferous reservoir of the third area in TAHE oilfield is a shallow sea and coastal clastic facies strata. The main oil-bearing layer is Kalashayi sand-shale sequence and growing inequality-thickness interbedded reservoir. The reservoir is characterized by the ultra-depth, small formation thickness, unstable sand distribution, oil-water coherent distribution, complex forming conditions, etc. Based on the problems such as thin oil reservoir and difficulties for tracking sand body, proceeding research on oil sand structure are carried out by wells calibration and three-dimensional seismic interpretation with the increasing of seismic resolution. The pseudo-wave seismic inversion technology is used to proceed reservoir space distribution features and improve the ability to identify the thin sand body. In the favorable reservoir distribution area, the integrated reservoir evaluation and conduct rolling deployment based on above techniques achieve good results and increase reserves and production.

**Key words** reservoir prediction; structure interpretation; reservoir description; carboniferous TAHE oilfield

## APPLICATION OF RADON-DETECTION FOR GROUNDWATER EXPLORATION IN QINGYUANSHAN OF QUANZHOU REGION

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Radon-detection is an effective geophysical radiometry. Because of the difference of structures between fractured rock and base-rock body, the abnormality of the concentration of radon could reflect the

state of fractures and could be used to analyze the extent of opening, connectedness, and the crashing extent of fractures. It can be made use of in exploration of groundwater and describing of the fractures character. Combining with the geological data, it could accurately be the base of exploration of groundwater resource. Here, for the aim of groundwater-rich zones, radon-detection was applied in exploration of fracture groundwater resource in Qingyuan mountain in Quanzhou, east-southern China. And the results shown that there was two obvious faults named F1 and F2 with the direction of North-West West and North-West in Qingyuan mountain. Combining with the geological data, F1 fault was engendered from orogeny and F2 fault was original from invading of granitoids and tectonic activity, they were an ideal reserving space of groundwater. And the extending of the faults was 2.5 km ~ 3.0 km, water catchment area was more than 13 km<sup>2</sup> with  $211 \times 10^4 \text{ m}^3/\text{a}$  of precipitation recharge, the storage of fracture groundwater was about  $5.1 \times 10^8 \text{ m}^3$ .

**Key words** radon-detection, radon anomaly, groundwater

## THE NEW AIRPORT SITE TESTING METHODS AND ENGINEERING GEOLOGY ANALYSIS BASED ON REMOTE SENSING AND GIS TECHNOLOGY

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In this paper, "3S" technologies (RS, GIS, GPS) are applied to the airport geological survey based on modern remote sensing technique. The up-to-date remote sensing image as LANDSAT, ETM image (spatial resolution 15m), SPOT image (spatial resolution 2.5m) and QUICKBird image (spatial resolution 0.61m), etc were taken as the information source, and through the digital processing such as remote sensing image data fusion, the numerical mosaics, image enhancement. The ortho-image map of different types, different bands and different resolutions are produced and the best images for airport Engineering Geology reconnaissance can be produced. Based on the remote sensing image enhancement processing, information extraction and GIS spatial analysis, we can interpret the geological structure and geological disaster with the tools of GPS. The method can be applied

in the field such as to do geological construction trait analysis, the analysis of distribution of hidden rupture and active rupture, furthermore the hydrogeological phenomena analysis as Karst funnel and hill-slope. The data it got above can be taken as the foundation for the project geological survey of XIAOSHAN airport.

**Key words** "3S" technologies, geological survey, airport selection, orthoimage

## MODELING METHODS OF DIGITAL ELEVATION MODEL FOR WATERWAY

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Based on the underwater terrain survey raw data obtained by GPS-RTK and depth sounder, the authors constructed a channels digital elevation model in Dongguan city by VC+ObjectARX CAD redevelopment and discussed the precision and efficiency of Several ways in Grid DEM construction. We conclude that the linear interpolation based on TIN is the high-efficiency and high-precision approach of constructing underwater Grid DEM, especially in the undulating terrain.

**Key words** digital waterway, underwater topographic survey, objectARX CAD+VC, DEM interpolation

## THE STUDY ON THE "3S" TECHNOLOGIES TO OPTIMIZE GEOPHYSICAL MEASUREMENTS

CHEN Liang, PANG Qing-heng, CUI Zhong-qiang (Institute of Geophysical and Geochemical Exploration, CAGS, Langfang Hebei 065000, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2011, 33(1): 87

In the design phase of geophysical measurement, the main reference points selection and network arrangement is mainly based on the map of cartography. But these topographic maps were drawn from the 1970s and 1980s, and they may have changed a bit, such as the water level of a lake, the expansion of urban residential change, the geological hazards, etc with the natural environment changes and human activities. With "3S" integration technologies getting to mature, the remote sensing image of geographical parameters can be used for correction of the map, and fully using the GIS technology optimize control net-