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艾维尔沟矿区煤层气控气地质条件分析

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摘要: 艾维尔沟矿区的煤层气赋存受到煤层埋藏深度、构造演化、煤变质程度、水文地质条件等因素的影响。从整体上看西部地区煤层埋藏较深, 煤质变质程度高, 东部逆冲断层发育, 对煤层气有较好的封存作用, 在开采过程中, 由于矿区受顶板岩性、水文等地质条件的影响, 煤层气含量较高。

关键词: 艾维尔沟矿区 煤层气富集 控气条件 地质构造演化

Gas Control Analysis Coalbed Methane in Geological Conditions Analysis of the Aiwergou Mining Area

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Abstract: The study shows that coalbed methane accumulation in the Aiwergou mine area is affected by factors such as coal seam depth, geological structure evolution, coal metamorphic degree, and hydrogeological conditions. Overall, the western part of the coal seam has a greater depth, higher coal metamorphic degree, and the eastern part has an uplifted fault, which has a good sealing effect on coalbed methane.

Keywords: Aiwergou mining area; coalbed methane enrichment; gas control conditions; geological structure evolution

1 矿区概况

艾维尔沟矿区位于新疆天山山脉境内, 属新疆吐鲁番盆地西翼, 是新疆重要的炼焦煤生产基地。

矿区出露层主要有石炭系、二叠系、三叠系、侏罗系等, 含煤地层主要是中下侏罗系统西山窑组(J_{2x})和八道湾组(J_{1b})。

构造煤储层应力释放渗透性演化数值模拟研究

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摘要: “应力释放改造-膨胀降压-解吸采气”的地面井开发技术有望成为实现构造煤煤层气规模化开发的关键突破。基于数值模拟研究, 揭示了应力释放作用下构造煤储层的渗透性演化规律: 随着有效应力降低, 煤体体积膨胀量、膨胀率及渗透率均显著上升。具体而言, 在相同卸压条件下: (1) 较低初始地层压力的储层卸载后体积膨胀更显著, 渗透率及其变化率增幅更大; (2) 糜棱煤渗透率增量高于碎粒煤; (3) 储层厚度减小时, 应力释放的影响范围受限, 渗透率改造范围随之缩小。

关键词: 数值模拟 构造煤 应力释放 体积膨胀 渗透率

Numerical Simulation Study on the Evolution of Permeability in Tectonic Coal Reservoirs Under Stress Release

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Abstract: The surface well development technology of “stress release transformation-swelling pressure reduction-desorption gas production” is expected to become a key breakthrough in achieving large-scale development of tectonic coal coalbed methane. Based on numerical simulation research, this study reveals the permeability evolution law of tectonic coal reservoirs under the action of stress release: as effective stress decreases, coal volume expansion, swelling rate, and permeability all increase significantly. Specifically, under the same pressure relief conditions: (1) Reservoirs with lower initial formation pressure exhibit more significant volume expansion after unloading, with greater increases in permeability and its rate of change; (2) The permeability increment of mylonitic coal is higher than that of granular coal; (3) As reservoir thickness decreases, the influence range of stress release becomes limited, and the range of permeability modification also shrinks.

Keywords: Numerical simulation, tectonic coal, stress release, volume expansion, permeability

一种地面井压裂井下长钻孔的 强化增透工艺技术研究

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摘要: 针对寺河煤矿西三集中回风巷掘进过程中工作面瓦斯浓度高、超前钻孔预抽效果差的问题。提出了通过地面煤层气井压裂井下定向长钻孔增加煤层透气性技术并进行了现场试验。该技术是利用井下掘进岩巷所揭露的地面煤层气井作为地面与井下连接通道, 采用高压油管作为压裂液流动管路, 在地面采用油气井压裂设备对井下定向长钻孔进行压裂, 然后再在井下针对压裂控制范围施工瓦斯抽放钻孔。通过现场实践表明, 地面钻井抽采可有效提升井下定向钻孔的抽采效率, 压裂后其抽采流量较压裂前可增长4倍以上, 回采面的回采进度基本可提高3倍以上, 有效提升了工作面的瓦斯治理能力和煤炭回采效率。

关键词: 压裂 煤层气井 定向长钻孔 瓦斯 透气性

Research on Enhanced Permeability Technology by Fracturing Underground Long Boreholes for Surface Wells

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Abstract: To address the problems of high gas concentration and poor pre-drainage performance of advanced boreholes during roadway excavation in the No. 3 West Centralized Return Airway of Sihe Coal Mine, a new technique that enhances coal seam permeability by fracturing underground directional long boreholes in surface coalbed methane wells is proposed and field-tested. This method utilizes existing coalbed methane wells exposed by underground roadway excavation as communication channels between the surface and underground. High-pressure tubing is used to transport fracturing fluid, and surface oil and gas well fracturing equipment is employed to fracture the underground directional boreholes. Gas drainage boreholes are drilled within the effective fracturing zone. Field practice shows that this method significantly improves the extraction efficiency of underground directional boreholes. Post-fracturing drainage flow rates increased by more than four times compared to pre-fracturing levels, and the advancement rate of the working face improved by over three times. This technique effectively enhances gas control capacity and coal recovery efficiency in the working face.

Keywords: Fracturing; coalbed methane wells; long directional borehole; gas; permeability

采用广域电磁法裂缝监测技术优化和 完善桥射联作压裂工艺

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摘要: 以“水平井+多段压裂”为核心的储层改造技术已成为中国油气开发向非常规等领域拓展的关键技术, 目前针对山西马必区块井区, 各簇射孔是否均匀开启无法确定, 每簇起裂、裂缝延伸、进液进砂、支撑剂铺置情况不明。引进广域电磁法裂缝监测技术对桥射联作工艺优化和完善, 其优化结果以3簇为主, 簇间距为40m左右, 一次暂堵, 120m³支撑剂, 2000m³液体左右, 15m³/min排量, 裂缝半缝长就可以达到80~100m, 即可满足220m井间距的要求。为下步压裂优化设计、井网部署或井网调整提供了依据。

关键词: 广域电磁法 桥射联作 煤层气

Optimization and Improvement of Bridge Plug and Perforation Fracturing Process Using Wide-Area Electromagnetic Fracture Monitoring Technology

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Abstract: Reservoir simulation technology based on horizontal wells with multi-stage fracturing has become a key approach in China's expansion into unconventional oil and gas development. In the Mabiz Block of Shanxi, it remains unclear whether perforation clusters are uniformly activated, and the initiation, extension, fluid and sand injection, and proppant distribution of each fracture are difficult to determine. To address these challenges, the wide-area electromagnetic fracture monitoring technology is introduced to optimize the bridge plug and perforation fracturing process. The optimization results suggest a configuration primarily based on three perforation clusters with a spacing of approximately 40 meters, using a single temporary plugging stage. The parameters include around 120m³ of proppant, 2,000m³ of fracturing fluid, and a drainage rate of 15m³/min. This setup can achieve a fracture half-length of 80 – 100 meters, meeting the 220-meter well spacing requirement. The results provide a solid foundation for future fracturing design optimization, well pattern deployment or adjustment.

Keywords: Wide-area electromagnetic method; bridge plug and perforation; coalbed methane

深部煤层气排采控制与工艺优化研究

——以延川南煤层气田为例

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摘要: 对延川南煤层气田在深部煤层气开发中的排采制度、工艺和工具研究细化, 由“缓泄压、稳液面、控套压”转变为“前期快排降流压、中期控压稳泵效、后期慢排稳产量、末期补液稳排采”的“一快三稳”排采制度, 控制流压降幅 0.19MPa - 0.12MPa - 0.02MPa; 高产气井采用井下掺水工艺, 中低产气井采用地面隔膜泵自动洗井工艺, 结合空心杆洗井工艺, 增加气井产液 $Q > 10.63\text{m}^3/\text{d}$, 配套自制高效气锚工具, 有效延长气井免修期。

关键词: 延川南煤层气田 深部煤层气 排采制度 排采工艺 排采工具

Research on Control and Process Optimization of Deep Coalbed Methane Extraction

—A Case Study of South Yanchuan Coalbed Methane Field

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(SINOPEC Linfen Coalbed Methane Branch, Shanxi 041000)

Abstract: The paper focuses on the refinement of the extraction system, process, and tools for deep coalbed methane development in the South Yanchuan Coalbed Methane Field. The drainage system shifts from “slow pressure relief, stable liquid level, and controlled casing pressure” approach to the “one fast and three stable” system characterized by: fast extraction to reduce flow pressure in the early stage, pressure control to stabilize pump efficiency in the mid-stage, slow extraction to stabilize production in the later stage, and liquid replenishment to stabilize extraction in the final stage. This results in controlled flow pressure decrease of 0.19MPa - 0.12MPa - 0.02MPa. High-production gas wells use underground water mixing technology, while medium and low-production gas wells use surface diaphragm pump automatic well washing technology, combined with hollow rod well washing technology, to increase gas well fluid production ($Q > 10.63\text{m}^3/\text{d}$). A self-made high-efficiency gas anchor tool is equipped, effectively extending the maintenance-free period of gas wells.

Keywords: South Yanchuan Coalbed Methane Field; deep coalbed methane; drainage and production system; drainage and production process; drainage tools

储层非均质性与煤层气开发工艺适配性研究

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摘要: 煤层气作为一种重要的清洁能源资源, 其开发与利用已成为全球范围内的关注焦点。然而, 在“三低一多”煤层特征背景下, 煤层气的储层非均质性和不同的开发工艺差异性为其高效开发带来了一系列挑战。文章对煤层气储层非均质性和不同工艺差异性进行研究, 深入研究储层非均质性对开发效果的影响方式, 并分析了储层类型成因、微观特征等方面对储层非均质性的影响, 最终从产气机理方面阐述了煤层气以“快速释放游离气能量、平稳激活并维系解吸过程”为核心的整体开发路线, 指明了深煤层上产方向, 助力煤层气开发。

关键词: 煤层气 储层非均质性 开发工艺差异性 渗透性 产能

Research on Reservoir Heterogeneity and Adaptability of Coalbed Methane Development Processes

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2. Technology Innovation Center of Coal Measure Gas Co-production, Shanxi 030008)

Abstract: Coalbed methane, as an important clean energy resource, has garnered global attention for its development and utilization. However, under the characteristics of “three lows and one high” of coal seams, the reservoir heterogeneity of coalbed methane and the differences in various development processes have brought a series of challenges to efficient coalbed methane development. This paper studies the heterogeneity of coalbed methane reservoirs and the differences among different processes, deeply investigates how reservoir heterogeneity affects the development effect, and analyzes the influence of the causes of reservoir type, microscopic characteristics and other aspects on reservoir heterogeneity. Finally, from the aspect of gas production mechanism, the overall development route of coalbed methane centered on “rapidly releasing the energy of free gas and smoothly activating and maintaining the desorption process” is expounded, indicating the direction of upward production in deep coal seams and facilitating the development of coalbed methane.

Keywords: Coalbed methane; reservoir heterogeneity; develop process differences; permeability; production capacity

扫描电镜下高、低阶煤岩的孔裂隙结构 特征差异及其对开发的影响研究

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摘要: 采用场发射扫描电子显微镜对高、低阶煤储层开展孔-裂隙特征研究, 对其微观孔-裂隙的类型、成因、空间分布和结构进行观测分析, 结合区块开发特征研究两者差异及其对开发影响。研究发现: 二者孔-裂隙发育特征主要受控于变质程度, 高阶煤煤化程度高, 孔-裂隙尺度小, 连通性差, 流体难以产出, 低阶煤煤化程度低, 孔-裂隙发育, 且以大孔级为主, 连通性好, 有利于流体运移, 但相对富水, 排水降压强度大。

关键词: 高、低阶煤岩 场发射扫描电镜 微观孔-裂隙通道结构 开发影响

Comparison and Analysis of Pore and Fracture Characteristics of High-Rank Coal and Low-Rank Coal under SEM

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Abstract: Field emission scanning electron microscope were used to study the pore-fracture characteristics of high-and low-rank coal reservoirs, based on the observation and analysis of the types, genesis, spatial distribution and structure of micro-pore-fissure in high and low rank coal, the pore-fissure system model is established. It is found that the characteristics of pore-fissure development are mainly controlled by the degree of metamorphism, high rank coal, small pore-fissure scale, poor connectivity, difficult to produce fluid, low rank coal, and pore-fissure development, it is characterized by large pore size, good connectivity and favorable for fluid migration, but relatively rich in water and high drainage pressure reduction strength.

Keywords: High-low rank coal; micropore-fracture; SEM; channel structure; development influence

1 实验过程

1.1 实验仪器与工作原理

该实验设备采用超高分辨率场发射扫描电镜,

品牌为德国蔡司, 型号为 GeminiSEM500。

1.2 样品信息与样品制作

实验选取了沁水盆地南部樊庄区块 FJ-1 井的
12 块高阶煤样品和二连盆地吉尔嘎朗图凹陷 JM18-

煤层气井产量递减与 EUR 预测方法的评价

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摘要: 随着当前煤层气开发工作的不断深入, 煤层气井控压生产制度得到广泛认可, 有效降低了储层应力敏感效应, 提高了生产井的估计最终可采储量 (EUR)。但是控压生产时, 气井工作制度频繁变化导致气量剧烈波动, 为准确预测单井 EUR 带来新的挑战。为揭示煤层气井产量递减规律、解决 EUR 预测时的不确定性问题, 以实际生产数据为例, 采用 PEworks 软件预测和经验式递减模型进行 EUR 计算。结果表明: PEworks 软件预测方法, 简便高效, 但是不同递减阶段进行预测, 预测结果不同, 增加了 EUR 预测的不确定性; 经验式递减模型分别利用 Arps 双曲递减模型和泛指数递减模型进行计算, 分别确认泛指数 $n=0.5$ 、 $m=0.5$ 时, 两种递减模型均获得最佳线性关系。

关键词: 煤层气 递减规律 EUR PEworks 产量递减模型

Production Decline of Coalbed Methane Wells and Evaluation of EUR Prediction Method

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Abstract: With the deepening of the current coalbed methane development work, the pressure control production system of coalbed methane wells has been widely recognized, which effectively reduces the reservoir stress sensitivity effect and improves the EUR of production wells. However, during pressure-controlled production, frequent changes in the working system of gas wells lead to violent fluctuations in gas volume, which brings new challenges to accurately predict the EUR of single wells. In order to reveal the production decline law of coalbed methane wells and solve the uncertainty problem in EUR prediction, taking the actual production data as an example, PEworks software prediction and empirical decline model are used to calculate EUR. The results show that the prediction method of PEworks software is simple and efficient, but the prediction results are different in different decreasing stages, which increases the uncertainty of EUR prediction. The empirical decline model is calculated by Arps hyperbolic decline model and pan-exponential decline model respectively. It is confirmed that when the pan-exponential $n=0.5$ and $m=0.5$, the two decline models obtain the best linear relationship.

Keywords: Coalbed methane; law of decline; EUR; PEworks; production decline model

致密气井小油管柱塞气举工艺携液能力研究

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摘要: 针对致密气井小油管柱塞气举工艺缺乏理论规范和工艺指导的问题, 通过建立柱塞气举套压模型与日排量计算模型, 结合临界气携液工艺约束条件, 模拟计算了1.9in小油管的柱塞气举工艺携液能力。通过系统研究得到: 在套管5½in-油管1.9in组合下, 当气源充足时可实现最大日排量21.77m³/d, 且与井深无关; 通过约束条件耦合分析, 首次建立了1.9in小油管柱塞气举日最大排量图版, 为致密气井小油管高效排水采气工艺参数优化提供了重要理论依据。

关键词: 致密气井 小油管柱塞气举 排水采气 临界携液模型 排量图版

Study on Liquid-Carrying Capacity of Plunger Lift Technology with Small-Diameter Tubing in Tight Gas Wells

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Abstract: To address the lack of theoretical standards and process guidelines for plunger lift technology in tight gas wells using small-diameter tubing (1.9in), this study establishes a casing pressure model and a daily liquid production model for plunger lift operations. Combined with the constraints of the critical gas-liquid carrying condition, the liquid-carrying capacity of plunger lift technology using 1.9in tubing is numerically simulated. Systematic research reveals that under the configuration of 5½in casing and 1.9in tubing, the maximum daily liquid production rate can reach 21.77m³/d when the gas supply is sufficient, independent of well depth. Through constraint coupling analysis, this study pioneers the development of a performance chart for maximum daily liquid production of 1.9in small tubing plunger lift systems, providing a critical theoretical foundation for optimizing water drainage and gas production parameters in tight gas wells with small-diameter tubing.

Keywords: Tight gas well; small-diameter tubing plunger lift; water drainage and gas production; critical liquid-carrying model; liquid production performance chart

瓦斯蓄热氧化利用项目中瓦斯浓度检测技术研究

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摘要: 在瓦斯蓄热氧化利用项目中, 常用的瓦斯浓度检测有基于 TDLAS 技术的原位激光检测仪和基于红外吸收法的红外检测仪。原位激光检测其优点是高精度、高灵敏度、响应时间短; 缺点是设备复杂, 成本较高。红外检测仪的优点非接触式测量、仪器本身反应速度快; 缺点是气体抽取的输送路线长, 影响了响应速度。针对这些问题, 本文以检测瓦斯浓度的快速性、精确性为目的, 设计了一套适用于低浓度瓦斯气体测量的检测系统, 满足实际的工程需求。

关键词: 瓦斯 浓度检测 蓄热氧化利用 快速熔断式气体检测仪

Research on Gas Concentration Detection Technology in Gas Thermal Storage Oxidation Utilization Project

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Abstract: In gas storage and oxidation utilization projects, commonly used gas concentration detection methods include in-situ laser detectors based on TDLAS technology and infrared detectors based on infrared absorption method. The advantages of in-situ laser detection are high precision, high sensitivity, and short response time; The disadvantage is that the equipment is complex and the cost is high. The advantages of infrared detectors are non-contact measurement and fast response speed of the instrument itself; The disadvantage is that the transportation route for gas extraction is long, which affects the response speed. In response to these issues, this article aims to achieve rapid and accurate detection of gas concentration, and designs a detection system suitable for low concentration gas measurement to meet practical engineering needs.

Keywords: Gas, concentration detection, thermal storage oxidation utilization, rapid melting gas detector

1 瓦斯蓄热氧化利用项目

1.1 瓦斯蓄热氧化利用项目工艺原理

风排瓦斯的浓度一般在 0.1% ~ 0.3%, 泵站抽采瓦斯的浓度范围较大, 浓度在 8% 以上。目

前利用途径主要是提纯输送、内燃机发电等, 瓦斯蓄热氧化利用主要是将风排瓦斯或者空气与浓度 8% 以下的低浓度瓦斯进行掺混, 形成 1.0% ~ 1.2% 浓度的掺混气, 由蓄热氧化设备的主风机推进旋转式蓄热氧化装置进口风管道, 掺混气经由旋