LOCATING AND EXTINGUISHING SUBSURFACE COAL FIRES.

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In subsurface coal fires in mines and waste banks, the application of any control method is made more difficult by the inability to accurately locate the fire. Combustion zones are discontinuous; and standard indicators, such as borehole temperatures or surface venting, rarely locate subsurface heated or cold areas. The Mine Fire Diagnostic Methodology has been used to determine the location and extent of combustion zones in abandoned mines. In this method, a characteristic fire signature is based on the ratio of higher molecular weight hydrocarbons (C2 to C5) to total hydrocarbons. Initially, samples are obtained at the bottom of boreholes under baseline or static conditions. A second set of samples is obtained under communication, i.e., when a suction fan is used to influence the direction of gas movement at the base of each borehole. Temperature and pressure data are also obtained to define the degree of communication between boreholes. The value of the ratio under communication conditions is taken as a measure of subsurface fire activity related to a particular flow direction. Using a Venn diagram technique, the results are mapped as quadrants on a borehole map of the site. Repetition of the communication tests provides overlapping quadrants that define hot, cold, and indeterminate areas.

A bituminous waste bank in Ohio that had been burning for approximately 30 years was the site of a test of cryogenic injection as a heat transfer method for extinguishing a subsurface fire. The cryogenic slurry was composed of CO2 particles in liquid N2 at a temperature of ¡V190 „aC. After injection into heated zones, the slurry absorbs heat, and conversion of the slurry to a gas creates a cold pressure front that forces heated combustion gases out of the bank. The 5000 m2 site was characterized by a three-dimensional array of temperature measuring points. Temperatures were measured over an 18 month period, before during and after two tests of cryogenic injection. Although the amount of cryogenic slurry injected was insufficient to completely extinguish the fire, injection of the slurry reduced the average temperature by approximately 15 „aC, and the cooling trend continued for 3 months. Evaluation of the temperature profiles indicated that cryogenic injection cooled localized hot spots and promoted environmental cooling of the more widely disbursed heated areas of the bank.

"CHANGE IN THE CENTRALIA COAL FIRE OVER TIME."

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Centralia, in the heart of the Pennsylvania anthracite region, burned a garbage dump in 1962 and in the process set the Buck Mountain coal vein on fire. This area is part of a syncline extending through Centralia toward Mt. Carmel. The coal beds are steeply folded and faulted (allowing for the movement of air), which makes underground fires difficult to put out. Due to a combination of geological structure and mine tunnels, the fire branched into four separate advancing fronts. Today the fire appears to be advancing on only two fronts.

This fire attracted peak media attention in the late 1970's and early 1980's when the ground collapsed under a small boy, who was not hurt; before that the fire had been ignored.

Early attempts to fight the fire included using fly ash barriers, which failed because of insufficient material. Trenching was tried, but not completed because the fire had advanced beyond expectations. In the late 1970's and early 1980's the government bought out most of the 1,000 plus landowners and allowed the fire to burn. Some residents understood the danger but, even now, refuse to leave; today less than 30 people reside in Centralia

Where the Centralia mine fire is widely known and studied, data are available to make an estimate on the rate of advancement.

COAL FIRE CONDENSATES: COLLECTION PROCEDURE, P-T STABILITY DIAGRAMS, ENVIRONMENTAL POLLUTION.

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Condensation products associated with the subsurface combustion of coal form as gas exhaled from surficial vents and fissures first cools and then condenses. Exhaled gas cools when it comes into contact with heat sinks such as rock, sediment, vegetation, water, and the atmosphere. A gas to solid phase transformation occurs when exhaled gas condenses below the gas-liquid transformation temperature. Careful collection procedures for obtaining condensates from vents and fissures are required to obtain material useful for analysis. In addition, extreme caution must be used to assure personal protection from hot and noxious vapors. A useful in situ technique for collecting condensates from inside vents and fissures is to scrape them with a metal spatula into a plastic or glass vial, being as careful as possible not to include any of the surrounding soil or rock, thereby making the separation process for analysis increasingly difficult. Condensates may also be collected in an analogous way from the underside of rocks overhanging fissures and also from ceramic tile placed over vents and fissures. The tile acts as a heat sink, thereby promoting condensation on the underside exposed to gas. X-ray diffraction, energy dispersive spectrometry, and scanning electron microscopy confirm numerous condensation products associated with coal fires including orthorhombic sulfur, gypsum, galena, selenium, pentlandite, and heazlewoodite. Using thermodynamic data available from the literature, P-T stability diagrams for coal gas to solid transformations are readily derived using a four step procedure structured around a closed thermodynamic cycle or Thermodynamic Loop. The method is applicable to gaseous condensation products associated with any geologic process and can incorporate any number of polymorphic phase transformations. The stability diagrams are useful environmental pollution indicators because they reveal conditions that favor the condensation of gaseous exhalations as opposed to their absorption into the atmosphere.

INTEGRATING SATELLITE REMOTE SENSING TECHNIQUES FOR DETECTION AND ANALYSIS OF UNCONTROLLED COAL SEAM FIRES IN NORTH CHINA.

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China is the biggest producer of coal in the world and mines about 1000 Mt of raw coal per year. Approximately 70 % of Chinas energy consumption is covered by coal. At the same time it is estimated that about 20 Mt of coal are being burnt in uncontrolled coal fires in China each year. Since these coal fires are spread out over the whole northern part of the country, stretching from Xinjiang province in the West to the Pacific coast in the East it is extremely difficult to keep an overview of the development of known fires as well as of newly developing ones.

Satellite remote sensing offers a powerful tool to observe and monitor such large regions, however, special methods and techniques have to be derived to accurately detect and monitor near surface coal seam fires. In this paper an integrated satellite remote sensing approach is described allowing to detect and monitor near surface coal seam fires by observing subtle land surface changes induced by the fires. These changes include: thermal surface anomalies, changes in spectral surface characteristics (vegetation cover and rock colour) as well as land subsidence caused by the fires.

The methods comprise the Radar interferometric generation of digital elevation models for geometric referencing and orthorectification of satellite imagery, the dedicated analysis of thermal satellite data (day-time and night-time), multispectral analysis of land surface properties as well as the mapping of small scale land subsidence by means of differential Radar interferometry. It is shown how these different satellite remote sensing methods can be synergistically combined to detect, analyse and monitor near surface coal seam fires in arid or semi-arid areas of North China. First results show the successful application of the methods and, furthermore, a comparison with ground measurements is given. While thermal and optical analysis of the fires can be considers as robust methods, the assessment of coal seam fires using differential Radar infererometry still has to be further developed in order to serve as reliable analysis tool. Within this work, a special focus is given to aspects of automation of the coal fire detection and analysis by means of satellite remote sensing in order to allow fire mapping in large areas with only minimal operator interaction.

COAL FIRES IN INDONESIA.

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Indonesia's fire and haze problem is increasingly being ascribed to large-scale forest conversion and land clearing activities making way for pulpwood, rubber, cocoa and oil palm plantations. Fire is the cheapest tool available to small land holders and plantation owners to reduce vegetation cover and prepare and fertilize extremely poor soils. Fires that excaped from agricultural burns have ravaged East Kalimantan forests on the island of Borneo durring extreme drought periods in 1982-83, 1987, 1994, 1997-98 and to a lesser extent in 2002. Estimates based on satellite data and ground observations are that more than 5 million hectares were burned in East Kalimantan during the 1997-98 fire season. Not only were the economic losses and ecological damage from these surface fires enormous, but they also ignited exposed coal seams along their outcrops.

Coal fires continue to threaten some of Indonesia's shrinking ecological resources in the Kutai National Park, Bukit Soeharto National Forest Park and Sungai Wain Nature Reserve. Sungai Wain has one of the last areas of unburned primary rainforest in the Balikpapan area with an extremely rich biodiversity. Although fires in 1997-98 damaged nearly 50% of this reserve and ignited 76 coal fires, it remains the most valuable water catchment area in the region and it has been used as a reintroduction site for the endangered orangutan.